THE TRILOBITES OF THE CARADOC SERIES IN THE CROSS FELL INLIER OF NORTHERN ENGLAND

BY

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SYNOPSIS

The trilobites known from the Caradoc Series in the Cross Fell Inlier are described and figured, many of them for the first time. They comprise fifty species and subspecies, assigned to twenty-eight genera and fifteen families. The relationships of the trilobites to those of other successions is reviewed. In the Longvillian and Marshbrookian Stages the fauna is of Anglo-Welsh type with occasional Baltic elements, but in subsequent stages the affinities with corresponding Norwegian and Swedish faunas becomes marked, reaching a maximum in the Pusgillian Stage.

I. INTRODUCTION AND ACKNOWLEDGMENTS

THE name Cross Fell Inlier is applied by geologists to the elongated area of Lower Palaeozoic rocks, a few miles north of Appleby, Westmorland, which extends in a south-south-easterly direction between the Carboniferous strata of the Pennines and the Permo-Trias of the Vale of Eden. The geological structure of the area is of great complexity and has been described by Shotton (1935). The disposition of the principal outcrops of Caradoc strata is shown in Text-fig. 1.

Although the first detailed stratigraphical accounts, accompanied by faunal lists, of the Caradoc Series in the Inlier were given during the last century by Harkness & Nicholson (1878), and Nicholson & Marr (1891), it was not until 1907 and 1910 that any figures and descriptions of trilobites were published. In those years Reed described four new species, *Lichas melmerbiensis*, *Acidaspis semievoluta*, *Homalonotus ascriptus* and *Trinucleus nicholsoni*, from strata which he called Dufton Shales at the road-section near Melmerby, as well as listing several other species from the same locality.

Bancroft (1933) listed a few Shropshire species of trilobites and brachiopods from the Inlier but it was not until 1936 that another trilobite was illustrated, when Shirley figured a specimen of *Flexicalymene onniensis*, a south Shropshire species, from an unspecified locality and horizon within the Dufton Shales of Pus Gill, near Dufton. In 1948 Bancroft's manuscript notes on the Cross Fell succession, including locality maps of Swindale Beck and part of Pus Gill, were published posthumously by Lamont, who added photographs of certain Shropshire specimens but figured none from the Inlier.

Since then a new genus, *Duftonia*, has been described from the Dufton Shales by the writer (Dean, 1959) who, in a later paper (1959*a*), discussed the detailed stratigraphy of the area and gave faunal lists. More recently some of the Trinucleidae occurring in the upper part of the succession have been described and figured (Dean, 1961). The present work aims at describing and figuring all the trilobites listed and discussed in the foregoing papers. Extensive collections of trilobites have been made during field-work financed in part by grants from the Gloyne Fund of the Geological Society of London, and I am grateful to the Council of the Society for their assistance. All the material is housed in the British Museum (Natural History), London. I wish to thank the Council of the Yorkshire Geological Society for permission to reproduce the sketch-map shown in Text-fig. 4. I am indebted to Mr. A. G. Brighton for the loan of type-specimens from the Sedgwick Museum, Cambridge, to my wife for her important share of the collecting, and to Professor W. F. Whittard who has kindly read and criticized the manuscript.

II. STRATIGRAPHICAL SUMMARY

The following table represents the subdivisions of the Caradoc Series which are generally recognized today in the main portion of the Inlier, together with the equivalent faunal zones as established in the type-area of south Shropshire.

The subdivision of the strata into Corona Beds and Dufton Shales is made on lithological grounds, the former including maroon and grey mudstones and shales

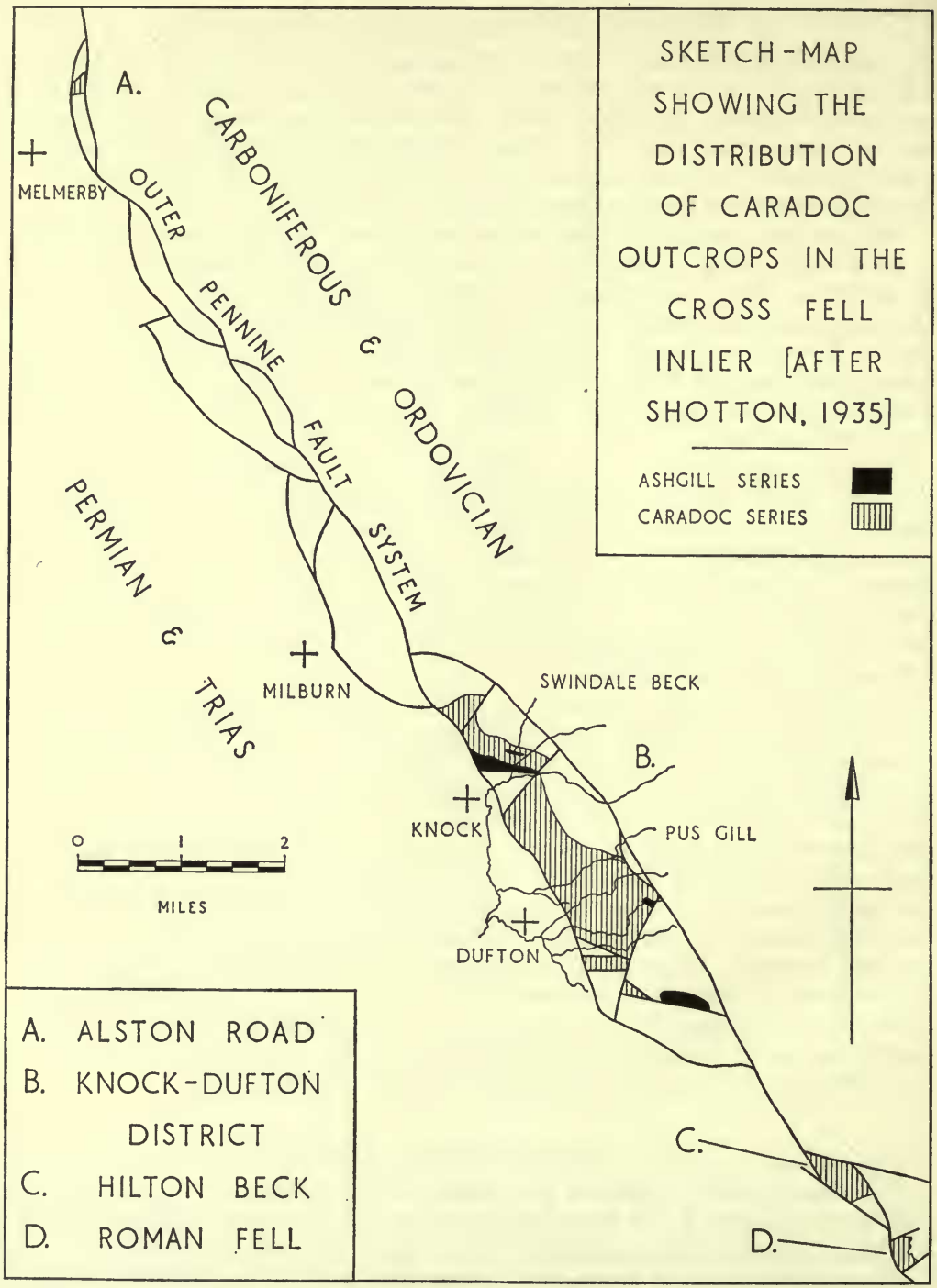
SKETCH-MAP SHOWING THE DISTRIBUTION OF CARADOC OUTCROPS IN THE CROSS FELL INLIER [AFTER SHOTTON, 1935]
ASHGILL SERIES
CARADOC SERIES
A.
MELMERBY
OUTER PENNINE FAULT SYSTEM
CARBONIFEROUS & ORDOVICIAN
PERMIAN & TRIAS
MILBURN
SWINDALE BECK
B.
KNOCK
PUS GILL
DUFTON
C.
D.
0 1 2
MILES
A. ALSTON ROAD
B. KNOCK-DUFTON DISTRICT
C. HILTON BECK
D. ROMAN FELL

FIG. 1.

Stage		Zonal Trilobite	Zonal Brachiopod	Lithological Subdivision
Pusgillian		—	—	Dufton Shales
Onnian		*Onnia superba*	—	
		Onnia gracilis	*Onniella broeggeri*	
		Onnia ? cobboldi	*Onniella inconstans*	
Actonian		*Platylichas laxatus*	*Cryptothyris paracyclica*	
Marshbrookian		*Broeggerolithus transiens*	*Onniella reuschi*	
			Dalmanella unguis	
			Dalmanella wattsi	
Longvillian	U	*Broeggerolithus longiceps*	*Kjaerina typa*	
			Kjaerina bipartita	
	L	*Broeggerolithus globiceps*	*Bancroftina typa*	Corona Beds
			Dalmanella indica and *D. lepta*	
			Dalmanella horderleyensis ?	

with occasional limestone bands, whilst the latter comprise essentially a rather monotonous series of dark-grey mudstones and shales with bands of nodular and impure limestone which often weather to a rotten-stone or " gingerbread " rock. The Corona Beds are shown in the table to coincide with the limits of the Lower Longvillian Substage, but in fact the zone of *Dalmanella indica* and *D. lepta* is the lowest faunal horizon definitely recognized, though the underlying zone may well be represented. The topmost zone of the Lower Longvillian is represented in the highest Corona Beds and it seems likely that there is a transition to the overlying Dufton Shales, but owing to extensive faulting the lowest zone of the Upper Longvillian has not been detected throughout the greater part of the Inlier. The remainder of the succeeding Caradoc strata as found in the Shropshire type-area are, for the most part, represented in the Cross Fell Inlier, with the addition of the Pusgillian Stage. This subdivision is held to constitute the topmost part of the Caradoc Series and to pre-date any known Ashgill strata. In Swindale Beck, near Knock, the Pusgillian is followed in the succession by the *Staurocephalus* or Swindale Limestone. The junction of the two has often been assumed to be conformable, but the writer believes there is a marked stratigraphical break above the Pusgillian, and that the Limestone represents a relatively high Ashgill horizon, as it is followed at Swindale Beck by Ashgill Shales with *Hirnantia sagittifera* (M'Coy). South-east of Dufton the Pusgillian outcrop is separated from that of the Swindale Limestone by a small thickness of strata, equated with part of the *Diacalymene* Beds of Cautley, which are probably overstepped by the Limestone.

The northernmost outcrops of Caradoc strata within the Inlier occur only in the vicinity of the village of Melmerby, after which they are known as the Melmerby Beds. The rocks have been divided into an upper and lower series; the Upper

Melmerby Beds contain a fauna indicative of the lower zone of the Upper Longvillian Substage, an horizon which, as stated earlier, is not yet known elsewhere in the Inlier. In the field, the Lower Melmerby Beds appear to underlie the upper beds stratigraphically and are considered to be of Lower Longvillian age; they contain abundant evidence of a Longvillian age but the zonal brachiopods of the Shropshire succession have not yet been detected and may be absent owing to the unsuitability of the environment. The rocks are mainly dark-green or maroon, blocky mudstones with occasional impure, nodular limestones. Their fauna includes a conspicuously large number of trinucleid trilobites, accompanied by common *Kloucekia apiculata* (M'Coy), features which readily distinguish them from the equivalent strata farther south in the Inlier, and which are more suggestive of corresponding North Welsh faunas.

No useful evidence has yet been obtained from the region to elaborate on the correlation between the shelly and graptolitic successions already put forward for south Shropshire (Dean, 1958 : 226). The Pusgillian, from its position above the Onnian (believed to represent the topmost *Dicranograptus clingani* Zone), is equated approximately with the *Pleurograptus linearis* Zone, and the shelly fauna suggests a correlation with Etage 4cα of southern Norway, an horizon which is itself correlated with that graptolite zone.

The fossil localities cited in the following descriptions are shown in Text-figs. 2–5. Text-fig 3 covers the well-known section of Swindale Beck, just north-east of the village of Knock; Text-fig 2 shows Pus Gill, north-east of Dufton; Text-fig. 4 covers the large area of east of Dufton, with the important sections of Dufton Town Sike, Billy's Beck and Harthwaite Sike; Text-fig. 5 shows the small, isolated outcrop of the Melmerby Beds north-east of Melmerby, near the northern end of the Inlier.

III. SYSTEMATIC DESCRIPTIONS

Family Raphiophoridae Angelin, 1854

Genus ***LONCHODOMAS*** Angelin, 1854

Type-species. *Ampyx rostratus* Sars, 1835 by subsequent designation of Bassler (1915 : 41).

Lonchodomas swindalensis sp. nov.

(Pl. 6, figs. 2, 6, 8)

1959*a*. *Lonchodomas* aff. *rostratus* (Sars) Dean, pp. 194, 207.

Diagnosis. *Lonchodomas* with glabella projecting only short distance in front of fixigenae. Pygidium semi-elliptical with four pairs of pleural furrows, the first pair being the most sharply defined.

Description. The material is fragmentary for the most part but includes two almost whole cranidia and one small, well-preserved pygidium. Excluding the

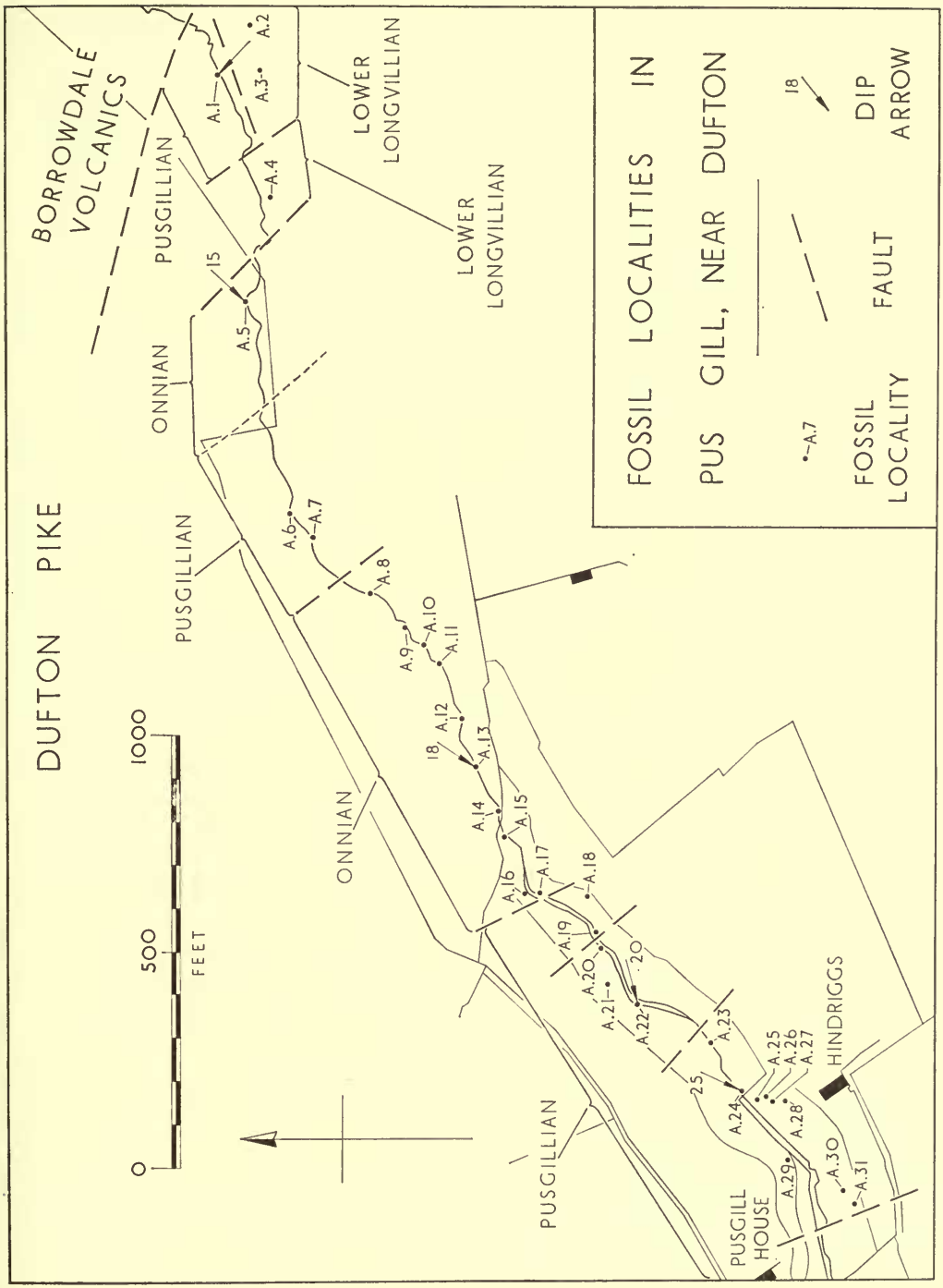
DUFTON PIKE
BORROWDALE VOLCANICS
PUSGILLIAN
ONNIAN
LOWER LONGVILLIAN
LOWER LONGVILLIAN
PUSGILLIAN
ONNIAN
PUSGILLIAN
HINDRIGGS
PUSGILL HOUSE
A.1
A.2
A.3
A.4
A.5
A.6
A.7
A.8
A.9
A.10
A.11
A.12
A.13
A.14
A.15
A.16
A.17
A.18
A.19
A.20
A.21
A.22
A.23
A.24
A.25
A.26
A.27
A.28
A.29
A.30
A.31
15
18
18
20
25
0
500
1000
FEET
FOSSIL LOCALITIES IN PUS GILL, NEAR DUFTON
FOSSIL LOCALITY
A.7
FAULT
18
DIP ARROW

FIG. 2.

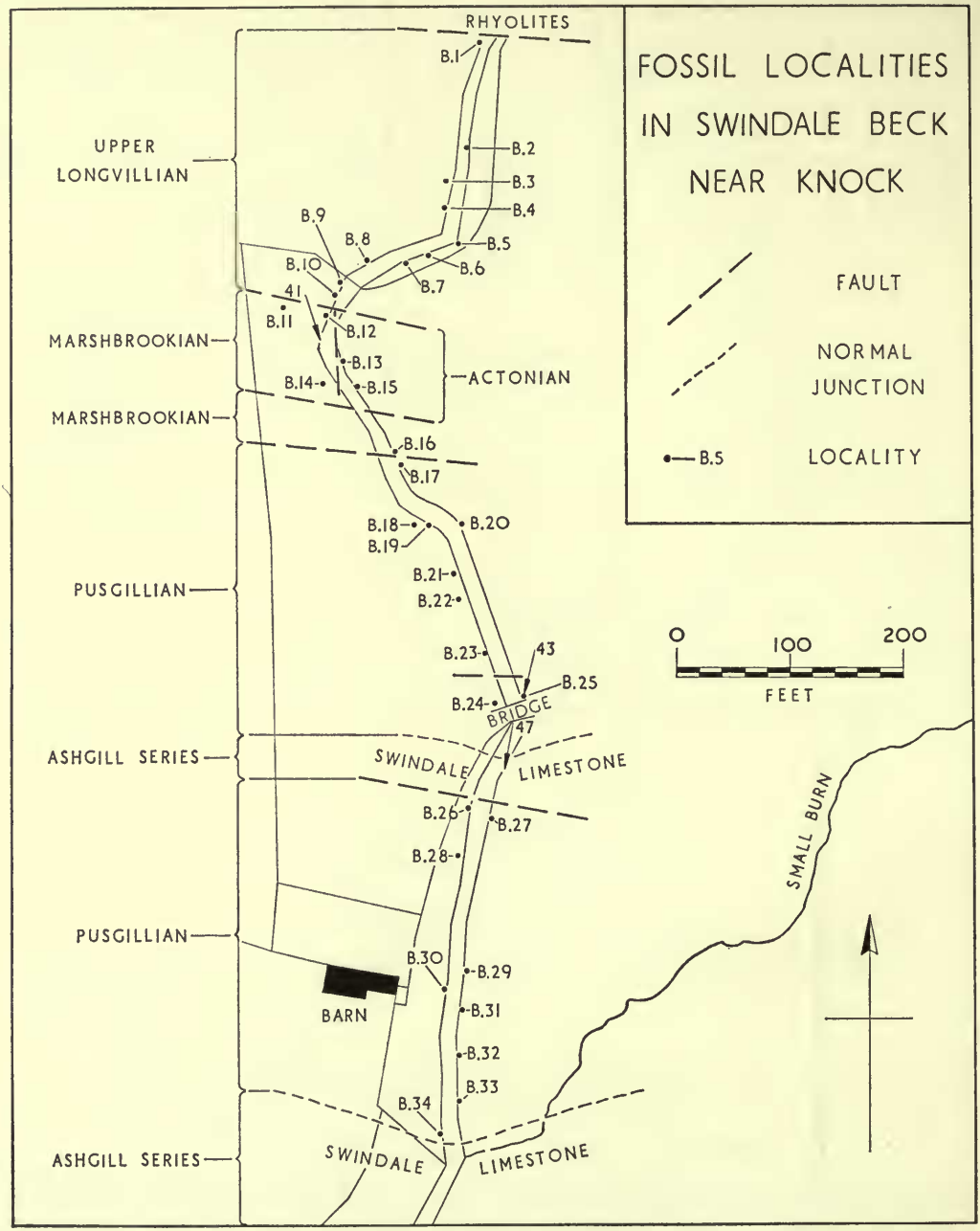
RHYOLITES
FOSSIL LOCALITIES IN SWINDALE BECK NEAR KNOCK
FAULT
NORMAL JUNCTION
B.5 LOCALITY
UPPER LONGVILLIAN
MARSHBROOKIAN
ACTONIAN
MARSHBROOKIAN
PUSGILLIAN
ASHGILL SERIES
PUSGILLIAN
ASHGILL SERIES
B.1
B.2
B.3
B.4
B.5
B.6
B.7
B.8
B.9
B.10
41
B.11
B.12
B.13
B.14
B.15
B.16
B.17
B.18
B.19
B.20
B.21
B.22
B.23
43
B.25
B.24
BRIDGE
47
SWINDALE
LIMESTONE
B.26
B.27
B.28
B.30
B.29
B.31
B.32
B.33
B.34
BARN
SWINDALE
LIMESTONE
SMALL BURN
0 100 200
FEET

FIG. 3.

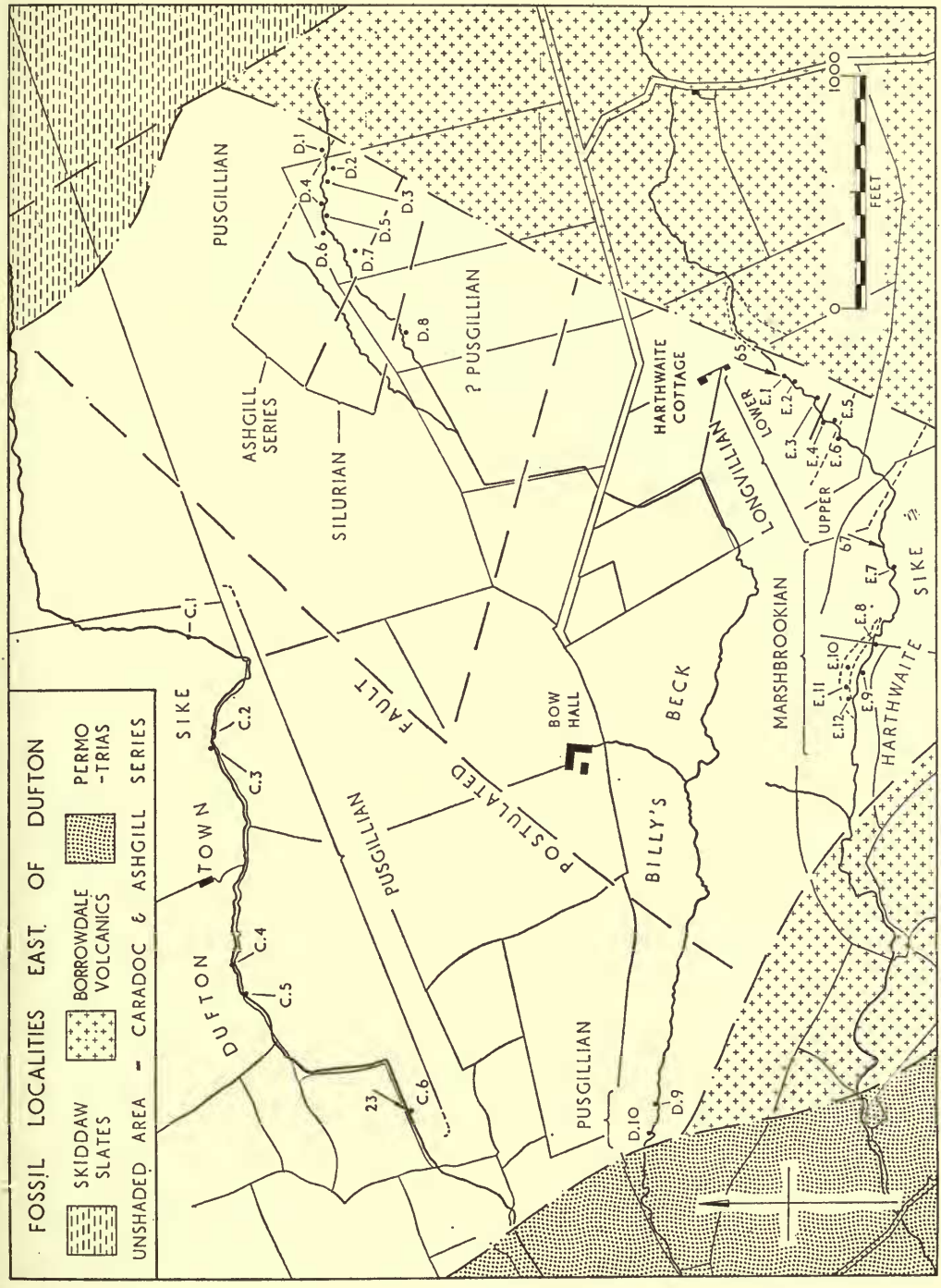
FOSSIL LOCALITIES EAST OF DUFTON
SKIDDAW SLATES
BORROWDALE VOLCANICS
PERMO-TRIAS
UNSHADED AREA - CARADOC & ASHGILL SERIES
PUSGILLIAN
ASHGILL SERIES
SILURIAN
? PUSGILLIAN
HARTHWAITE COTTAGE
LONGVILLIAN
LOWER
UPPER
MARSHBROOKIAN
HARTHWAITE
SIKE
BECK
BILLY'S
BOW HALL
POSTULATED
FAULT
TOWN
DUFTON
1000
FEET
0

FIG. 4.

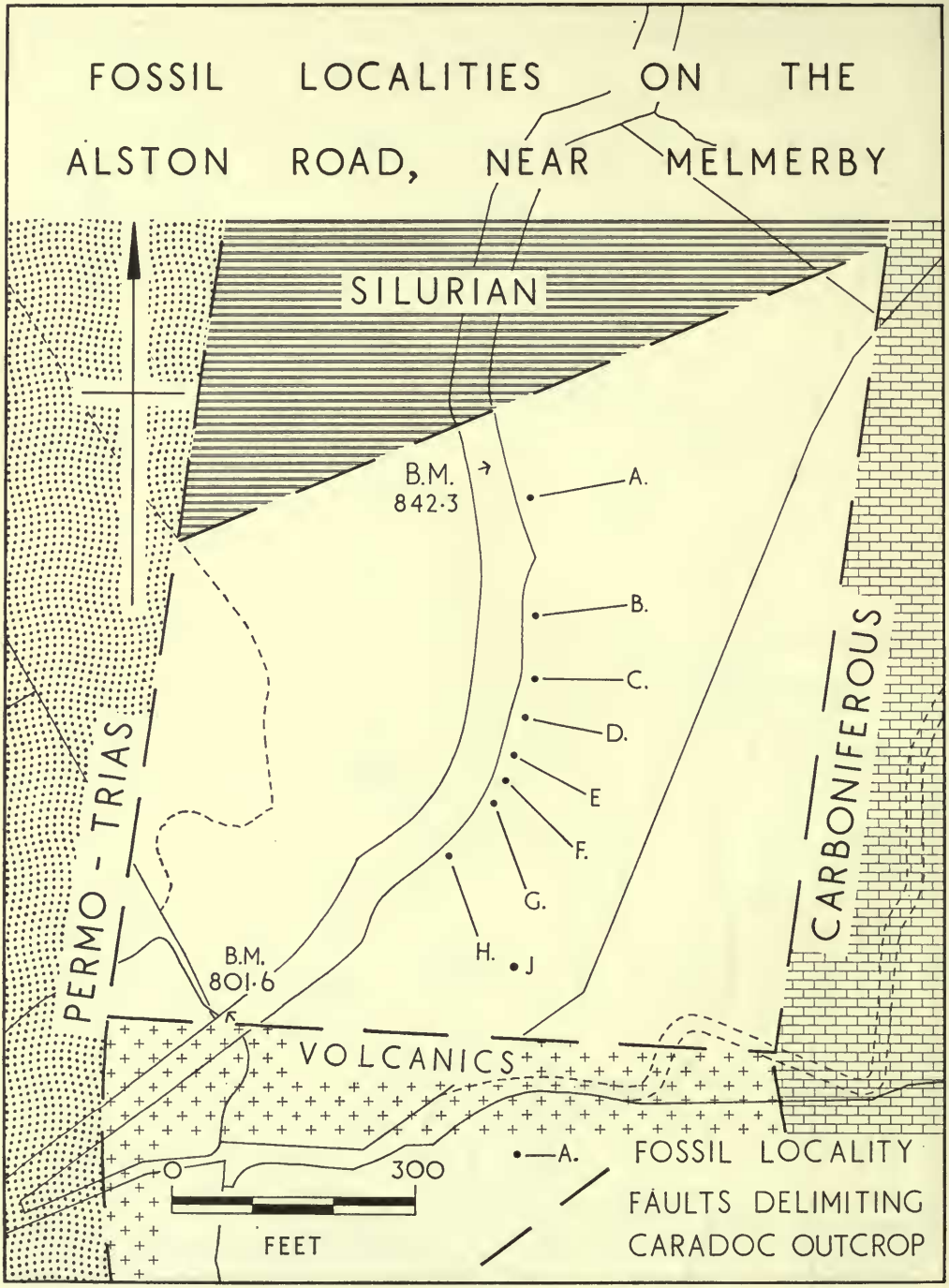
FOSSIL LOCALITIES ON THE
ALSTON ROAD, NEAR MELMERBY
SILURIAN
B.M.
842·3
A.
B.
C.
D.
E
F.
G.
H.
J
B.M.
801·6
PERMO - TRIAS
CARBONIFEROUS
VOLCANICS
300
FEET
A. FOSSIL LOCALITY
FAULTS DELIMITING
CARADOC OUTCROP

FIG. 5.

frontal spine, the dimensions of the cranidia, numbered respectively In. 49946 and In. 49968, are as follows : length, 5 mm., breadth, 9 mm. ; length, 11 mm. ; breadth, 16 mm. Dimensions of the pygidium, In. 49967, are : length, 1·5 mm., breadth, 4·5 mm. The cranidium is roughly rhomboidal in plan, produced anteriorly into a long, frontal spine, the surface of which bears fine, longitudinal striae. The glabella attains its greatest breadth at its mid-point and is bounded by almost straight axial furrows containing slot-like hypostomal pits, situated frontally. One cranidium (Pl. 6, fig. 2) shows a faint median ridge extending from near the occipital furrow to the base of the frontal spine, where it is replaced by a groove ; similar grooves occur on the sides and undersurface of the frontal spine as in other species of *Lonchodomas*, giving rise to the fluted, quadrate cross-section characteristic of the genus. The posterior margin of the cranidium, and the pleuroccipital furrows are parallel, transversely straight except medially where, owing to a small extension of the glabella, they are convex backwards.

The pygidium is semi-elliptical in outline with a strongly-curved, steeply-declined, posterior border which carries fine, parallel terrace lines, though the latter are not visible in the photograph (Pl. 6, fig. 6). The anterior margin is straight medially but curves forwards a little anterolaterally. There are four pairs of pleural furrows, the first pair being the most deeply impressed ; all are deepest anterolaterally becoming faint at, or near, the shallow axial furrows. No axial rings are visible.

Horizon and Localities. All the known specimens have been collected from Dufton Shales belonging to the upper half of the Upper Longvillian Substage in Swindale Beck. There they occur in association with *Kjaerina geniculata* Bancroft, *Reuschella* sp. nov. and *Dolerorthis* sp. The figured specimens are from localities B. 5 and B. 6, but the same form has been found also at B. 10 (see Text-fig. 3). These are the only records of *Lonchodomas* from the Upper Longvillian of the Anglo-Welsh area.

Holotype. In. 49968 (Pl. 6, fig. 2).

Paratypes. In. 49946 (Pl. 6, fig. 8) ; In. 49967 (Pl. 6, fig. 6).

Discussion. The Swindale Beck species bears an obvious relationship to *Lonchodomas rostratus* (Sars) which has been refigured by Størmer (1940 : 128, pl. 2, figs. 1–4). The latter species has, however, a smaller proportion of the glabella projecting in front of the fixigenae, and the pygidium of the Norwegian form, the type-specimens of which were obtained from the Ampyx Limestone (zone of *Nemagraptus gracilis*) near Oslo, differs also in having only one pair of well-defined, distally situated, pleural furrows, which die out before attaining the axial furrows.

Lonchodomas politus (Raymond, 1925 : 39, pl. 2, figs. 8, 9 ; Cooper, 1953 : 18, pl. 6, figs. 1, 2, 5–10), from the " Upper Lenoir Limestone " of Black River age in Tennessee, has a conspicuously punctate test and a pygidium bearing seven or eight pairs of furrows, only the first of which is deeply impressed, but otherwise much resembles the Cross Fell species.

The stratigraphically younger species *Lonchodomas pennatus* (La Touche), discussed elsewhere in the present paper, has a relatively larger proportion of the glabella projecting in front of the fixigenae, whilst the pygidium has a less well-differentiated axis than that of *L. swindalensis*, and only one pair of pleural furrows.

Lonchodomas pennatus (La Touche)

(Pl. 6, figs. 1, 3–5, 9, 12)

1884. *Ampyx pennatus* La Touche, p. 57, pl. 3, fig. 56.
1891. *Ampyx tetragonus* Angelin : Nicholson & Marr, p. 511.
1932. *Ampyx* (*Lonchodomas*) *pennatus* La Touche : Reed, p. 205, pl. 11, figs. 5–7.
1949. *Lonchodomas pennatus* (La Touche) Bancroft, p. 299, pl. 10, fig. 17.
1958. *Lonchodomas pennatus* (La Touche) : Dean, pp. 213, 224.
1959*a*. *Lonchodomas pennatus* (La Touche) : Dean, pp. 200, 207.
1960. *Lonchodomas pennatus* (La Touche) : Dean, p. 82, pl. 11, figs. 2, 5, 8–12.

Several cranidia agreeing in all essentials with La Touche's species have been collected from the Dufton Shales. The often indifferent preservation renders precise measurement difficult, most of the specimens being compressed vertically, but the proportions are close to those of similarly preserved Shropshire material, the length of the cranidium, measured from the base of the frontal spine to the posterior margin of the occipital ring, being slightly more or less than three-quarters of the maximum breadth. A feature not previously seen in *L. pennatus* but now preserved in one specimen (Pl. 6, fig. 1) is the retroussé form of the prismatic frontal spine, which curves forwards and gently upwards from the glabella : a similar curvature is seen also in *Ampyx salteri* Hicks and *Ampyx linleyensis* (Whittard, 1955, pl. 1, fig. 17 ; pl. 2, fig. 6). A few individuals have traces of a slight median ridge or carina on the glabella, and this may be either accentuated by lateral compression or absent altogether. A similar ridge occurs in some Shropshire specimens, but its presence varies with the state of preservation. Two probably immature pygidia from Cross Fell (Pl. 6, fig. 5) are proportionately broader than the *forma typica*, their length : breadth radio being 1 : 3, but in mature pygidia this changes to about 1 : 2, that is to say, generally comparable with the Shropshire material.

Horizon and localities. In the Knock-Dufton district *Lonchodomas pennatus* appears for the first time in the Onnian Stage, *Onnia gracilis* Zone, of Pus Gill, at localities A. 8, 9, 12 and 14. It has been found less commonly in the overlying *Onnia superba* Zone of Pus Gill, at localities A. 5 and 16. The ensuing Pusgillian Stage has yielded specimens at both Pus Gill, localities A. 6, 18 and 28, and Swindale Beck, locality B. 25.

Discussion. La Touche's holotype was obtained from the Onnian Stage, *Onnia superba* Zone, in the Onny Valley of south Shropshire, in which district *Lonchodomas pennatus* ranges upwards from the Actonian Stage (Dean, 1960 : 83). The discoveries in the Pusgillian Stage of the Cross Fell Inlier increase the known vertical range of the species, but there is no information yet regarding its relationship to still younger forms, though there is a general resemblance to certain species of Ashgill age, for example that figured by Reed (1905 : 97, pl. 4, fig. 2) as *Ampyx* (*Lonchodomas*) cf. *rostratus* Sars from the Slade Beds of Haverfordwest.

Elsewhere, a small cranidium of *Lonchodomas* which may be conspecific with *L. pennatus* has been figured by Størmer (1945, pl. 2, fig. 10) as *Lonchodomas* aff. *rostratus* (Sars) from the *Tretaspis* Shales of Hadeland, a horizon approximately equivalent to the Pusgillian Stage. *Lonchodomas carinatus* (Cooper, 1953 : 17, pl. 7,

figs. 12–17, 19–23) from the Black River Stage of Tennessee bears a strong resemblance to *L. pennatus* but possesses an irregularly punctate test, and the glabella projects less far forwards in front of the fixigenae. The pygidium of *L. carinatus* differs in having at least four discernible axial rings.

Family Trinucleidae Hawle & Corda, 1847

Subfamily Cryptolithinae Angelin, 1854

Genus ***BROEGGEROLITHUS*** Lamont, 1935

Type Species. *Cryptolithus broeggeri* Bancroft, 1929 by original designation.

Broeggerolithus nicholsoni (Reed)

(Pl. 6, figs. 7, 11?, 14? ; Pl. 7, figs. 1–12)

1891. *Trinucleus goldfussi* Barrande ?, Nicholson & Marr, p. 509.
1891. *Trinucleus seticornis* Hisinger ?, Nicholson & Marr, p. 509.
1910. *Tinucleus nicholsoni* Reed, p. 212, pl. 16, figs. 1–9.
1912. *Trinucleus nicholsoni* Reed : Reed, pl. 18, fig. 6 ; pl. 19, figs. 4, 4*a*.
1914. *Trinucleus gibbifrons* M'Coy : Reed, p. 356, pl. 29, fig. 6.
1914. *Trinucleus nicholsoni* Reed : Reed, p. 357.
1927. *Cryptolithus nicholsoni* (Reed) Stetson, p. 88.
1940. *Broeggerolithus nicholsoni* (Reed) Whittington, p. 245.
1948. *Broeggerolithus nicholsoni* (Reed) : Bancroft *in* Lamont, p. 416.
1959*a* *Broeggerolithus nicholsoni* (Reed) : Dean, pp. 212, 214, 220.
1960. *Broeggerolithus* sp. (? nov.) Dean, p. 119, pl. 17, fig. 12.
1960. *Broeggerolithus simplex* Dean, p. 120, pl. 17, fig. 14.

Description. The cephalon is sub-semicircular in outline, broader than long, the maximum breadth of the syntypes ranging from 14 mm. to about 22 mm. The glabella is of moderate breadth, equal to about two-thirds of the total length, and often carries a small, apical ocellus just forward of centre. A pair of small, basal, glabellar furrows with apodemes is located immediately in front of a second pair of apodemes situated at the distal ends of the occipital furrow. The glabella is separated from the convex cheek-lobes by moderately-deep, almost straight, axial furrows. The occipital ring is small, strongly convex transversely, produced backwards and upwards to form a broadly-based occipital spine. The cephalic fringe is moderately declined, both frontally and laterally, though this may not always be apparent owing to compression of the specimen within a shaly matrix. The upper surface of the fringe is generally smooth and there is no development of raised interradial ridges such as are found in some earlier species of *Broeggerolithus*, for example *B. broeggeri* (Bancroft). One or two specimens show suggestions of such ridges, but these are almost certainly due to crushing and are not of constant form. There are four concentric rows of fringe-pits in front of the glabella, where the breadth (*sag.*) of the fringe contracts slightly so as to accommodate the frontal lobe of the glabella. There is a strong radial arrangement of pits frontally, and this

persists laterally. The concentric arrangement is also marked, and the variation and norm of the four outer rows of pits is as follows : E_2 = 19–24 (22), E_1 = 21–23 (21), I_1 = 21–22 (22), I_2 = 20–22 (21). Up to three pits of E_2 may be missing at the genal angle, and in certain rare instances an occasional pit of E_2 may be absent laterally or anterolaterally. There is a notable lack of auxiliary E_2 pits such as are found laterally in certain related species of *Broeggerolithus*. There is little marked differentiation in the size of pits, but those of I_1 and I_2 are slightly larger than the others, especially towards the posterior margin of the fringe. E_2 and E_1 are sited close together, but E_1 and I_1 are separated by a smooth, narrow, concentric " band " corresponding in position with a conspicuous girder on the underside of the fringe. A similar band of equal breadth separates I_1 and I_2, marking the position of a second less well developed pseudo-girder. There are seven to nine, most commonly eight, pits along the posterior margin of the fringe. I_3 usually comprises fourteen or fifteen small pits, and is developed from R11 or thereabouts. The posterior margins of the fringe run slightly backwards, delimiting small genal prolongations, towards the genal angles which are produced to form librigenal spines ; the latter curve gently outwards and backwards, and their length is at least equal to that of the cephalon.

One of the syntypes, A. 29607, retains only five thoracic segments of typical trinucleid form. The axis of each is narrow (*tr.*) and bears a pair of apodemes situated just above the axial furrows. On each pleura, a moderately-deep pleural furrow, situated just forwards of centre, runs obliquely backwards from the axial furrow to the pleural point. A complete topotype thorax (Pl. 7, fig. 4) exhibits the customary complement of six thoracic segments.

The syntype pygidium, A. 29615 (Pl. 7, fig. 2), is preserved as an internal mould and few details can be seen. The axis has three clearly defined axial rings, and three or four more are less well defined. The pleural lobes have three, or perhaps four, segments, separated by faint pleural furrows and widening (*exsag.*) towards the lateral margins.

Horizon and localities. All Reed's syntypes were described by him as having been collected solely from the Alston Road cutting near Melmerby, but the state of preservation of most of the specimens indicates that they came from what are known as the Lower Melmerby Beds, and the probable type-locality is believed to be that shown in the present paper as locality J (see Text-fig. 5). One syntype, Sedg. Mus. A. 29614, is preserved differently from the rest and the matrix suggests a probable origin in the Upper Longvillian strata such as are found at Alston Road, locality H. All the other localities, from A to G, along the Alston Road have yielded *Broeggerolithus nicholsoni*, but the specimens are, in general, smaller than the syntypes.

Although trinucleid trilobites are so abundant almost everywhere at the Alston Road outcrop, elsewhere in the Inlier they are almost unknown from strata of Longvillian age. An uncommon exception is locality E. 3 at Harthwaite Sike where rare fragments, referred to *B.* cf. *nicholsoni* (see Pl. 1, figs. 11, 14), occur with an assemblage indicating the *Bancroftina typa* Zone of the Lower Longvillian.

Lectotype, here chosen. Sedg. Mus. A. 29613 (Pl. 7, figs. 6, 9).

Paratypes. Sedg. Mus. A. 29607 ; A. 29608 ; A. 29609 (Pl. 7, figs. 1, 7) ; A. 29610 (Pl. 7, fig. 10) ; A. 29611 (Pl. 7, fig. 5) ; A. 29612 (Pl. 7, fig. 8) ; A. 29614 (Pl. 7, fig. 11) ; A. 29615 (Pl. 7, fig. 2).

Discussion. In a recent account of trinucleid trilobites in south Shropshire (Dean, 1960 : 103) the species assigned to the genus *Broeggerolithus* were divided into three groups on the basis of small but significant differences in the structure of the cephalic fringe. *B. longiceps* (Bancroft) and *B. transiens* (Bancroft) were placed together in Group 3, whilst *B. simplex* Dean was placed doubtfully in Group 2. The last-named species is here regarded as a synonym of *B. nicholsoni* and may also be placed in Group 3. *B. simplex* was founded on a small cranidium from the Lower Longvillian of the Onny Valley and was at that time believed to be distinct. The pit count, however, falls within the limits of variation now established for *B. nicholsoni*, and additional material from Shropshire tends to confirm the identity of the two species

The fringe of *Broeggerolithus transiens* closely resembles that of the Melmerby species but its pit-count for the four outermost rows is noticeably smaller, and there are a few auxiliary pits situated anterolaterally in E_2. *Broeggerolithus longiceps* is remarkably similar to *B. nicholsoni*. The former species is, unfortunately, known from only a comparatively small population sample in south Shropshire, but as far as can be ascertained the pit-count falls within the limits of that for *B. nicholsoni*. Like *B. transiens*, however, *B. longiceps* generally possesses a few auxiliary pits in E_2, though situated posterolaterally, and these have not been found in *B. nicholsoni*. It is not known whether this is an invariable characteristic of *B. longiceps*, but if this should not prove to be the case then there is no other valid reason for regarding the species as distinct from *B. nicholsoni*. Certain well-preserved Shropshire specimens of *B. longiceps* have reticulate cheek-lobes, a feature not seen on any of the syntypes of *B. nicholsoni* but found on several specimens of the latter species from the Upper Melmerby Beds of the Alston Road cutting.

Outside the Cross Fell Inlier *Broeggerolithus nicholsoni* probably occurs at several localities in North Wales, associated with faunas of Longvillian age.

Broeggerolithus melmerbiensis sp. nov.

(Pl. 6, figs. 10, 13)

1959*a*. *Broeggerolithus* aff. *nicholsoni* (Reed) *pars*, Dean, p. 214.

Diagnosis. Large *Broeggerolithus* generally similar to *B. nicholsoni* but with large number of fringe-pits, about one hundred, in four outermost concentric rows. Both E_1 and E_2 extend to the genal angles.

Description. One well-preserved specimen collected from the Alston Road cutting appears to resemble *Broeggerolithus nicholsoni* in most respects, but possesses a number of fringe-pits much larger than the norm for that species. The specimen has a closely similar radial and concentric arrangement of pits, but particularly noticeable is the manner in which rows E_2 and E_1 are placed close together, whilst rows E_1 and I_1 are separated from each other by a wide, concentric " band " which

coincides with the girder on the underside of the fringe. I_1 and I_2 are similarly separated from each other, and the pits composing these two rows become larger in size towards the posterior margin of the fringe. A conspicuous feature is the way in which both E_1 and E_2 are developed as far as the genal angles. Both I_3 and I_4 consist essentially of pits which are comparatively small, though increasing slightly in size posteriorly, and the two rows are developed respectively from R13 and R19. The pit count for the specimen is as follows : E2 = 24 pits, E1 = 25 pits, I1 = 26 pits, I2 = about 25 pits. There are four continuous concentric rows of pits in front of the glabella, and seven pits are situated along each posterior margin of the fringe. The total number of pits in rows E2 to I2 inclusive is about one hundred, compared with an average of about eighty-five in *Broeggerolithus nicholsoni* (*s. s.*). The single available cranidium possesses four attached thoracic segments of typical *Broeggerolithus* aspect, but the total number originally present is unknown, as is the pygidium.

Horizon and locality. The holotype was collected from a loose nodule of impure limestone immediately below locality A in the Alston Road cutting, three-quarters of a mile north-east of Melmerby (see Text-fig. 5). It is almost certain that the specimen did, in fact, derive from this locality. The horizon is in the Longvillian Stage, and the strata at this point are believed to be the Upper Melmerby Beds, of Upper Longvillian age (Dean, 1959*a* : 213). The associated fauna includes *Broeggerolithus nicholsoni*, *Brongniartella* and *Flexicalymene*.

Holotype. BM. In. 52558.

Discussion. Although bearing a general resemblance to certain other species of *Broeggerolithus* such as *B. nicholsoni*, *B. longiceps* and *B. transiens*, the new form is unlikely to be confused with them on account of its much higher pit-count for the four outer rows, whilst no other species exhibits a comparable development of E_2 to the genal angles.

Broeggerolithus cf. ***transiens*** (Bancroft)

(Pl. 8, figs. 1, 3, 4, 6, 8, 11)

1929. *Cryptolithus transiens* Bancroft, p. 90, pl. 2, fig. 5.
1959*a*. *Broeggerolithus transiens* (Bancroft) Dean, pp. 196–8, 207.
1960. *Broeggerolithus transiens* (Bancroft) : Dean, p. 123, pl. 18, figs. 2, 3, 7, 8, 11, 14. This reference contains a list of all other synonyms.

Numerous cephala and cranidia have been found, agreeing in all essentials with the description of the species from the type-area of south Shropshire (Dean, 1960 : 123). The pit count for the various rows of the cephalic fringe falls within the limits of variation of the Shropshire specimens, but instead of having one or two pits of E_1 marginal at the genal angle, the Cross Fell specimens commonly have three pits so situated, though the number has been found to vary from one to four. Generally there are up to two auxiliary pits in the outermost concentric row, E_2, of the Shropshire specimens, and these may sometimes be absent from the Cross Fell examples. This casts some doubt on the validity of such a feature as a means of separating closely-related species, but too few complete cranidia are available from either

Shropshire or Cross Fell to give reliable statistics for the variation in E_2. An analogous situation has already been noted with regard to *Broeggerolithus nicholsoni* and *B. longiceps*. The species is more abundant in the mudstones of the Cross Fell Inlier than in the corresponding coarser sediments of south Shropshire, and individuals frequently attain a larger size, the largest-known cephalon having a breadth of about 25 mm.

Horizon and localities. In the Knock-Dufton district *Broeggerolithus* cf. *transiens* is fairly common in Dufton Shales of the Marshbrookian Stage at Swindale Beck. There it occurs in small numbers in strata thought to belong to the middle portion of the stage (locality B 12), but becomes more abundant in higher strata (localities B. 11, 14, 16) which contain *Kjerulfina* cf. *polycyma* Bancroft and are considered to be equivalent to the *Onniella reuschi* Zone of south Shropshire. *B.* cf. *transiens* occurs also in Harthwaite Sike, east-south-east of Dufton (see Text-fig. 4) at localities E. 7, 8, 9?, 10–12, but the fauna there is sparse, composed in the main of smaller individuals.

Broeggerolithus sp.

(Pl. 8, fig. 2)

1959*a*. *Broeggerolithus* sp. (pars.) Dean, p. 207.

Among the numerous trinucleid trilobites found in the Marshbrookian rocks of Swindale Beck is one individual quite different from all the rest. The specimen comprises a fragmentary cranidium preserved as a limonitic external mould in a dark-grey, cleaved mudstone. The estimated length and breadth of the original cephalon are respectively 12 mm. (approx.) and 26 mm. Its most distinctive feature is the manner in which the two outermost concentric rows of pits, E_2 and E_1, end abruptly without extending to, or even near, the genal angle as is customary in normal forms of *Broeggerolithus*. E_2 extends only to the anterolateral angle, leaving three pits of E_1 external to the margin. E_1 stops far short of the genal angle, leaving five pits of I_1 external to the margin, though separated from it by a smooth band which is equal in breadth to one row of pits. Such an arrangement results in the somewhat unusual, indented form of the cephalic margin in front of the genal angle, and the obliquely truncated shape of the anterolateral angle. The estimated number of pits originally present is as follows: $E_2 + e_2 = 12$, $E_1 + e_1 = 15$, $I_1 + i_1 = 19$, $I_2 + i_2 = 19$, $I_3 + i_3 = 10$. There is a small triangular group of eight pits situated between I_2 and I_3 near the posterior margin of the fringe, and seven pits are aligned parallel to the latter. The pits of E_1 and I_{1-2} are of roughly equal size, larger than those of E_2 and I_3. The last four pits of I_2 nearest the posterior margin are of particularly large size.

Horizon and locality. Found in mudstones of the Dufton Shales which contain *Broeggerolithus* cf. *transiens* (Bancroft) and *Kjerulfina* cf. *polycyma* (Bancroft), and belong to the topmost part of the Marshbrookian Stage, at locality B. 16 in Swindale Beck.

Discussion. It is not unusual for specimens of *Broeggerolithus* to have a deficiency in the number of E_2 pits near the genal angle, and in such forms as *B.*

soudleyensis (Bancroft) and *B. globiceps* (Bancroft) some E_2 pits may be absent frontally, but no known species compares in any way with the excessive loss of pits in the specimen now figured. In view of the large number of specimens of normal *Broeggerolithus* cf. *transiens* associated with the cranidium it seems likely that the specimen represents a rare mutation or pathological form. Consequently it is not proposed to erect a new specific name, at least until further material is available.

Genus ***ONNIA*** Bancroft, 1933

TYPE SPECIES. *Cryptolithus superbus* Bancroft, 1929 by original designation of Bancroft (1933 : 2).

Onnia gracilis (Bancroft)

(Pl. 8, figs. 12, 13)

1929. *Cryptolithus gracilis* Bancroft, p. 94, pl. 2, figs. 8, 9.
1959*a*. *Onnia gracilis* (Bancroft) Dean, p. 207.
1960. *Onnia gracilis* (Bancroft) : Dean, p. 130, pl. 19, figs. 2, 7. This reference contains a comprehensive synonymy of the species.

This species has recently been redescribed in detail by the writer (Dean, 1960 : 130) who gave the following figures for the range in variation of the number of pits present in the outermost four rows of the fringe. $E_2 + e_2 = 31–37$ (34), $E_1 + e_1 = 21–25$ (22), $I_1 + i_1 = 21–25$ (23), $I_2 + i_2 = 21–25$ (23) The figure in brackets represents the mode. Insufficient well-preserved material is available from the Cross Fell Inlier to give authentic figures for the corresponding variation, but the available material has yielded the following results: $E_2 + e_2 = 32–37$, $E_1 + e_1 = 20–23$, $I_1 + i_1 = 20–22$, $I_2 + i_2 = 21–22$. It is therefore apparent that the specimens fall within, or are very close to, the permissible variation for the species in its type-area.

HORIZON AND LOCALITIES. As in south Shropshire *Onnia gracilis* characterizes the middle portion of the Onnian Stage. It has been found in some abundance in black mudstones of the Dufton Shales at Pus Gill, localities A. 8, 9, 11, 12, 13, 14 and 15. Again, as in Shropshire, the species is accompanied by a fauna which includes *Onnicalymene onniensis* (Shirley), *Lonchodomas pennatus* (La Touche), *Chonetoidea* sp. and *Onniella broeggeri* Bancroft.

Onnia superba (Bancroft) ***pusgillensis*** Dean

(Pl. 8, figs. 5, 7, 9, 10)

1961. *Onnia superba pusgillensis* Dean, p. 120, pl. 7, figs. 1–6. Includes full synonymy.

Onnia superba (Bancroft), the zone fossil of the topmost subdivision of the Onnian Stage in south Shropshire, has not been found in the Cross Fell Inlier, but is thought to be represented by a distinct, and possibly local, subspecies *O. superba pusgillensis*. Although resembling *O. superba* in almost all respects the Cross Fell form may easily be distinguished by the continuous development of I_2 in front of the

glabella, and by the greater development of I_3 and I_4, respectively from R3 or R4, and R7.

HOLOTYPE. BM. In. 55707.

PARATYPES. BM. In. 50005 (Pl. 8, fig. 9) ; In. 50008 (Pl. 8, fig. 5) ; In. 50049 ; In. 55704 ; In. 55705 ; In. 55706 ; In. 55708.

HORIZON AND LOCALITIES. Dufton Shales, Onnian Stage, *Onnia superba* Zone, Pus Gill, localities A. 5 and A. 16.

Subfamily TRETASPIDINAE Whittington, 1941

Genus *TRETASPIS* M'Coy, 1849

TYPE SPECIES. *Asaphus seticornis* Hisinger, 1840 by subsequent designation of Bassler (1915 : 1285).

Tretaspis cf. *ceriodes* (Angelin) *donsi* Størmer

(Pl. 10, figs. 4, 6, 8)

1945. *Tretaspis ceriodes* (Angelin) var. *donsi* Størmer, p. 405, pl. 1, fig. 8.
1959*a*. *Tretaspis* cf. *ceriodes* (Angelin) : Dean, p. 207.
1961. *Tretaspis* cf. *ceriodes donsi* Størmer : Dean, p. 129, pl. 9, figs. 7–9.

In southern Norway, *Tretaspis ceriodes donsi* has been shown by Størmer (1945 : 404) to be restricted to the upper part of the Upper Chasmops Limestone, 4bδ. The earliest-known occurrence of *Tretaspis* in the Cross Fell Inlier is at Pus Gill, locality A. 13, in Dufton Shales belonging to the *Onnia gracilis* Zone of the Onnian Stage, and the evidence at this point, though fragmentary, suggests a comparison with the Norwegian subspecies. Additional, better-preserved material from the *Onnia superba* Zone at Pus Gill, locality A. 5, is too incomplete for detailed comparison, but shows all the principal features of *T. ceriodes donsi*. The horizon of the Cross Fell specimens corresponds fairly closely with that of the Norwegian material.

Tretaspis convergens Dean

(Pl. 10, figs. 1, 3, 5)

1961. *Tretaspis convergens* Dean, p. 127, pl. 9, figs. 1–6.

A detailed description of this species has already been given (Dean, 1961 : 127) to which nothing need be added here. *T. convergens* is a distinctive form, its closest relationships being with the species-group typified by *Tretaspis seticornis* (Hisinger), particularly *T. seticornis* var. *anderssoni* Størmer (1945 : 402, pl. 1, fig. 2). *T. convergens* has so far been found at only one locality in the Cross Fell Inlier, namely B. 25 in Swindale Beck. There it occurs in the highest part of the Dufton Shales, belonging to the Pusgillian Stage, so that it is generally contemporaneous with *Tretaspis seticornis anderssoni* and allied forms as found in Etage 4cα of southern Norway.

HOLOTYPE. BM. In. 50059*a*, *b* (Pl. 10, figs. 1, 3, 5).

Paratypes. In. 50030 ; In. 50037 (Pl. 10, fig. 2) ; In. 50058*a*, *b*.

Tretaspis kiaeri Størmer *radialis* Lamont

(Pl. 9, figs. 2–4)

1941. *Tretaspis kjaeri* mut. *radialis* Lamont, 1941, p. 456, figs. 5, 6.
1961. *Tretaspis kiaeri radialis* Lamont : Dean, p. 122, pl. 7, figs. 7–9, pl. 8, figs. 1, 3–5. Includes full synonymy of the subspecies.

The majority of the abundant specimens of *Tretaspis* collected from the Dufton Shales of the Cross Fell Inlier can be referred to this subspecies. *T. kiaeri radialis* was founded originally on two fragmentary specimens from the Portrane Limestone of Eire, but the description has since been supplemented, using material from the Dufton Shales (Dean, *loc. cit.*), and the affinities with other species discussed.

Horizon and localities. All the known specimens are from Dufton Shales belonging to the Pusgillian Stage. The exact distribution within the Pusgillian is not clear, owing to the predominance of successions affected by strike-faulting, but the subspecies appears to occur throughout most of the stage. Localities include the following : Pus Gill, A. 6, A. 18, A. 21, A. 24 to A. 30 ; Swindale Beck, B. 18, B. 22 to B. 26, B. 28, B. 33, B. 34 ; Dufton Town Sike, C. 1 to C. 6 ; Billy's Beck, D. 1 ; also the section at Hurning Lane, one mile north of Dufton.

Tretaspis kiaeri Størmer *duftonensis* Dean

(Pl. 9, figs. 1, 5–7)

1961. *Tretaspis kiaeri duftonensis* Dean, p. 125, pl. 8, figs. 2, 6–8.

The subspecies was described from a single, well-preserved specimen collected from Dufton Shales belonging to the Pusgillian Stage at Pus Gill, locality A. 27. Its closest relationship would appear to be with *T. kiaeri radialis*, from which it differs in having a conspicuously larger pit-count for E_{1-2}, a less well-developed concentric arrangement of I_{2-4} posterolaterally, as well as a larger, triangular area of irregularly arranged pits on the genal prolongations of the fringe. *T. kiaeri duftonensis* is not known with certainty outside the type-locality, though fragments of fringe suggest that it may occur elsewhere at Pus Gill, but identification is difficult in the absence of better-preserved material.

Holotype. BM. In. 50020a, b.

Family Cheiruridae Salter, 1864

Subfamily Cyrtometopinae Öpik, 1937

Genus *PSEUDOSPHAEREXOCHUS* Schmidt, 1881

Type species. *Sphaerexochus hemicranium* Kutorga, 1854 by subsequent designation of Reed (1896*a* : 119).

Pseudosphaerexochus cf. *octolobatus* (M'Coy)

(Pl. 10, figs. 7, 9–12)

?1891. *Youngia trispinosa* Nicholson & Etheridge : Nicholson & Marr, p. 511.
1959*a* *Pseudosphaerexochus* sp. nov., Dean, pp. 204, 208.

Description. The cephalon is known only from the cranidium. The glabella is strongly convex both longitudinally and transversely, subovate in plan, its maximum breadth about, or slightly greater than, three-quarters of the sagittal length. It is bounded by deep, evenly-curved axial furrows, strongly convex abaxially, with deep, hypostomal pits. The frontal lobe is small, rather less than one-quarter of the glabellar length, and there are three pairs of equispaced glabellar furrows. The first and second pairs are parallel, extending inwards about one-quarter of the glabellar breadth ; they intersect the axial furrows at right-angles, but curve thence adaxially backwards, at the same time becoming rapidly shallower. The first and second pairs of glabellar lobes are identical in size and form, their convexity in line with the remainder of the glabella. The third glabellar furrows are deeper than, and parallel to, the first and second pairs, but curve backwards without reaching the occipital furrow and become shallower proximally. The occipital ring is small, narrow (*tr.*), strongly convex transversely, separated from the glabella by a moderately deep occipital furrow. The fixigenae are small, convex, and steeply declined abaxially. The pleuroccipital segment becomes slightly longer (*exsag.*) laterally, ending posterolaterally in a pair of short, broad, blunt fixigenal spines set a short distance inwards from the lateral margins. The pleuroccipital furrow is transversely straight for the most part, becoming shallower distally where it curves forwards towards, though without reaching, the lateral margins. The eyes have not been found preserved. The palpebral lobes are narrow, moderately convex abaxially, strongly arched longitudinally, and slightly divergent backwards ; they are defined proximally by palpebral furrows of moderate depth which die out quickly to both front and back. The anterior branches of the facial suture extend forwards from the eyes, parallel to the axial furrows, to cut the anterior border, whilst the posterior branches curve backwards distally to intersect the lateral margins just in front of the line of the pleuroccipital furrow. The librigenae have not been found. The surface of the glabella is covered with fine, evenly distributed granules, whilst all the furrows are smooth. The surface of the fixigenae is covered with large, dispersed pits, the intervening spaces, together with the surface of the pleuroccipital segment, being covered with smaller punctae which are apparent only on the external mould. The internal mould of the glabella is ornamented with closely-grouped, small, prickly granules, probably representing the infillings of canals in the original test.

The hypostoma and thorax are not known.

An incomplete pygidium, which must have been more than twice as broad as long, is the only specimen that has been found (Pl. 10, fig. 7). It is made up of four segments which are produced backwards to form four pairs of strong, tapering spines ; the latter are separated from one another by well-defined notches, and their tips are stepped backwards slightly *en echelon* from first to fourth. Only three

axial segments are visible, the first two well defined by deep ring furrows, and the third poorly defined by two shallow transverse notches near the bases of the fourth pair of pleural spines. The axial furrows comprise broad, shallow grooves, moderately convergent backwards. Excluding the furrows, the surface of the pygidium is granulate on the internal mould, but finely pitted on the external mould.

Horizon and localities. The earliest-known occurrence of the species in the Cross Fell Inlier is in the Dufton Shales, Onnian Stage, *Onnia superba* Zone of Pus Gill, locality A. 5. Most of the available specimens are, however, from Dufton Shales belonging to the Pusgillian Stage at Swindale Beck, locality B. 25. Other localities, all in Pusgillian strata, are at Pus Gill, localities A. 6 and A. 30, and at Dufton Town Sike, locality C. 6, east of Dufton.

Discussion. The specific name *Pseudosphaerexochus octolobatus* has been used to cover forms of the genus occurring in British Ordovician strata of various ages. The holotype, described and figured by M'Coy (1849 : 407 ; *in* Sedgwick & M'Coy, 1851, pl. 1G, fig. 10) as *Ceraurus octolobatus*, is a pygidium, Sedg. Mus. A. 11606, from the Rhiwlas Limestone, of Ashgill age, near Bala, and the species must be redescribed in detail before satisfactory comparisons can be made. Specimens from the Ashgill Series, Drummuck Group, of Girvan were assigned by Reed (1906 : 141, pl. 18, figs. 8–11) to *Cheirurus* (*Cyrtometopus*) *octolobatus*, and these appear to be identical with the Cross Fell specimens, at least as far as the cephalon is concerned.

Pseudosphaerexochus has been recorded from the Onnian Stage of the Onny Valley in south Shropshire (Dean, 1961*a* : 316), but the material there is too fragmentary for comparison with that from Cross Fell.

Family Encrinuridae Angelin, 1854

Subfamily Encrinurinae Angelin, 1854

Genus ***ENCRINURUS*** Emmrich, 1844

Type species. *Entomostracites punctatus* Wahlenberg, 1821 by original designation of Emmrich (1844 : 16).

Encrinurus sp.

(Pl. 11, figs. 1, 4)

1959*a*. *Encrinurus* sp., Dean, p. 214.

Only one specimen has been collected, a pygidium about 5 mm. long and 4·5 mm. broad frontally, preserved as an internal mould with part of the corresponding external mould. Frontally the axis occupies about one-quarter of the maximum breadth ; it is delimited by deep, smooth axial furrows and tapers backwards to a narrow tip. There are eight pairs of pleural ribs which terminate laterally in small free points ; the pleurae of the eighth pair almost coalesce with the terminal piece of the axis, from which they are separated by a pair of shallow grooves. The axis as far as the eighth pair of pleurae carries fifteen axial rings, but beyond this position is apparently smooth. The ring furrows, apart from the first three or four, become

shallower medially and there are traces of small median nodes on the third, fifth and eighth axial rings. The remainder of the dorsal surface is smooth.

Horizon and locality. Locality H (see Text-fig. 5) beside the Alston Road, three-quarters of a mile north-east of Melmerby. The strata, the Upper Melmerby Beds, contain fossils indicating the lower part of the Upper Longvillian Substage, the equivalent of the *Kjaerina bipartita* Zone or Alternata Limestone in south Shropshire.

Discussion. Few Caradoc species of *Encrinurus* are available for comparison. *Encrinurus* sp. (? nov.) from the Marshbrookian Stage of Shropshire (Dean, 1961*a*, pl. 49, figs. 10, 12) has a similar number of ribs but a larger number of axial rings, at least seventeen. The Alston Road specimen may well prove to represent a new species.

Subfamily Dindymeninae Přibyl, 1953

Genus ***DINDYMENE*** Hawle & Corda, 1847

Type species. *Dindymene fridericiaugusti* Hawle & Corde, 1847 by subsequent designation of Barrande (1852 : 816).

Dindymene duftonensis sp. nov.

(Pl. 11, fig. 13)

1959*a*. *Dindymene* sp. nov., Dean, pp. 198, 207.

The holotype is an incomplete cranidium of estimated breadth 4 to 5 mm., excluding fixigenal spines, the maximum breadth being roughly twice the length. The glabella is strongly convex, both longitudinally and transversely, narrow posteriorly but expanding forwards until equal to rather more than one-third of the cephalic breadth. The axial furrows are deep and narrow posteriorly, but widen forwards where they curve distally to join the lateral border furrow which skirts the plump fixigenae. The occipital furrow is shallow and broad (*sag.*) medially, deepening laterally where a pair of deep apodemal pits is situated ; the occipital ring is small, curving forwards abaxially to form a pair of occipital lobes. The pleuroccipital segment is uniformly narrow (*exsag.*), transversely straight, separated from the fixigenae by a parallel, moderately-deep, pleuroccipital furrow. The external mould shows that the narrow (*tr.*) lateral borders meet the pleuroccipital segment at the genal angles which are produced to form a pair of fixigenal spines, long, slender, slightly curved, convex side forwards, and broadly splayed backwards. The surface of the fixigenal spines, lateral border and pleuroccipital segment is uniformly and finely granulate, appearing almost smooth. The surface of each fixigena is covered with fine wrinkles, which contain numerous small pits, and carries seven large tubercles ; three of the latter are situated anterolaterally in a row parallel to the lateral border furrow, one is situated medially just in front of the pleuroccipital furrow, and the remainder are arranged more or less sporadically over the fixigena. The surface of the glabella, though incomplete, is estimated to have carried about twenty tubercles of moderate size. Three of these form a median, longitudinal row

extending half-way from the occipital furrow to the front of the glabella and are flanked by two pairs of tubercles situated a short distance adaxially from the axial furrows. The remaining tubercles are grouped more closely together across the frontal lobe, and the intermediate spaces are finely granulate. These figures apply to the partially preserved holotype, and the material available is insufficient to decide whether there is any variation in the disposition of the tubercles.

The remainder of the exoskeleton is unknown.

Horizon and locality. Dufton Shales belonging to the Marshbrookian Stage, probably the middle or upper third, at locality E. 12 (see Text-fig. 4) in Harthwaite Sike, east-south-east of Dufton.

Holotype. BM. In. 54652*a*, *b*, the latter, an external mould, being figured here in the form of a latex cast.

Discussion. The known species of *Dindymene* were reviewed recently by Kielan (1959 : 146 *et seq.*). Of them, the species with which *D. duftonensis* may best be grouped are *D. ornata* Linnarsson, of Ashgill age, and *D. plasi* (Kielan, 1959 : 151, pl. 29, figs. 1–3) from the Llanvirn Series of Bohemia. Like them it is equipped with genal spines directed posterolaterally, but those of the Cross Fell species are notably longer. Both the extra-British species differ from *D. duftonensis* in having a particularly large tubercle, almost a cephalic spine, sited medially, one-third of the distance from the occipital furrow to the front of the glabella ; in this respect they somewhat resemble the more extreme development of a cephalic spine seen in the recently described *Cornovica*, from the Lower Llanvirn of west Shropshire (Whittard, 1960 : 122), a genus which possesses, however, glabellar furrows and eleven thoracic segments. The fixigenae of *D. duftonensis* carry a similar number of large tubercles to those of *D. plasi* and *D. ornata* : the glabella, however, has a greater number of tubercles than that of *D. ornata* but fewer than that of *D. plasi*. As with *D. ornata* the space between the glabellar tubercles is finely granulate, a feature apparently not found in *D. plasi*.

Harper's (1956 : 389) record of *Dindymene* cf. *ornata* from Upper Longvillian strata at Llanystwmdwy, Carnarvonshire, suggests that *D. duftonensis* may possibly be represented in the North Welsh faunas.

Dindymene sp.

(Pl. 11, fig. 6)

1959*a*. *Dindymene* sp., Dean, pp. 194, 207.

Two fragmentary cranidia, one of which is figured here, have been collected from the Upper Longvillian of Swindale Beck. In size and general form they match the type material of *D. duftonensis* but, as the dorsal surface is not preserved, precise identification has not been possible, though there are faint traces of some large tubercles. The more complete specimen has a narrow (*sag.*), upturned, anterior border, apparently separated from the glabella by a narrow (*sag.*), anterior border furrow containing the facial suture. The latter follows the outline of the frontal lobe as far as the axial furrow, beyond which it runs parallel to the margin of the cephalon and separates a narrow (*tr.*), smooth border from the fixigena. It has not

been possible to trace the line of the suture beyond the anterolateral portion of the glabella.

Horizon and locality. Dufton Shales containing *Kjaerina geniculata* Bancroft and forming the upper part, the *Kjaerina typa* Zone, of the Upper Longvillian Substage, at locality B. 5 in Swindale Beck.

Subfamily Cybelinae Holliday, 1942

Genus ***ATRACTOPYGE*** Hawle & Corda, 1847

Type species *Calymene verrucosa* Dalman, 1826 by original designation of Hawle & Corda (1847 : 90).

Atractopyge scabra sp. nov.

(Pl. 11, figs. 2, 3, 10)

1891. *Cybele verrucosa* Dalman : Nicholson & Marr, pp. 505, 511.
1959*a*. *Atractopyge* aff. *aspera* (Linnarsson) : Dean, p. 207.

Diagnosis. Glabella clavate, slightly broader than long, with frontal lobe strongly convex forwards. Three pairs equisized glabellar lobes. Eye-ridges run from palpebral lobes towards first glabellar furrows. Surface of test, excluding furrows, covered with coarse tubercles, some of conspicuously large size. Pygidium longer than broad. Four pairs of ribs ending in free points arranged *en echelon*. Narrow axis with four continuous axial rings and a further fifteen or sixteen incomplete rings.

Description. The length of the cranidium is rather more than half the breadth. The glabella is moderately convex, clavate in outline, and attains its maximum breadth, slightly greater than the median length, across the lateral extremities of the anterior border. There are three pairs of glabellar furrows, represented by deep, almost slot-like pits situated a short distance adaxially from the axial furrows. The first pair of glabellar furrows is situated about mid-way between the frontal margin and the occipital furrow, the second and third pairs being then positioned at regular intervals so as to give three pairs of almost equisized glabellar lobes, their long axes strongly divergent forwards. The occipital ring is short (*sag.*), convex forwards medially ; laterally it curves forwards slightly to form a pair of occipital lobes, immediately in front of which a pair of apodemal pits is situated at the extremities of the broad (*sag.*), smooth, moderately-deep occipital furrow. The axial furrows are deep, wide (*tr.*), smooth, and rounded basally in cross-section ; from the occipital ring they follow a slightly divergent course forwards as far as the first glabellar furrows, whence they diverge more sharply to the false preglabellar field. The frontal lobe of the glabella is strongly convex forwards where it is bounded by a broad (*sag.*), smooth furrow, well defined but not deep, which intersects the axial furrows opposite a pair of deep, hypostomal pits. Beyond this furrow the anterior border is only slightly raised, but it is rendered more conspicuous by the presence thereon of a row of well-developed tubercles of both large and medium size. Ornamentation of similar type, but including a greater number of large tubercles, covers

the surface of the remainder of the glabella with the exception of the glabellar lobes. In some individuals two, or even four, of the largest tubercles on the anterior border may be arranged symmetrically about the sagittal line, and two or three pairs of those on the main body of the glabella have been found to behave similarly, but it has not proved possible to utilize satisfactorily, with the available material, the notation proposed by Tripp (1957) for the tuberculation of certain species of *Encrinurus*. The fixigenae are strongly convex, with faint suggestions of eye ridges running towards the first glabellar furrows, and are surmounted by prominent, pedunculate, palpebral lobes. No palpebral furrows have been seen on the latter, which have a finely granulate, almost smooth surface, contrasting with the coarse tuberculation of the fixigenae which ends abruptly at the base of the palpebral lobes. The pleuroccipital furrow is straight for about half its length (*tr.*) but then turns markedly backwards and finally dies out just before reaching the lateral margins. The pleuroccipital segment, which follows the course of the pleuroccipital furrow, is extremely narrow (*exsag.*) near the axial furrows but then widens appreciably towards the apparently rounded genal angles. Each half of the pleuroccipital segment carries about seven or eight tubercles arranged fairly regularly along its length (*tr.*).

The librigenae, hypostoma and thorax are not known.

Only a few isolated pygidia have been found, the largest of which is just over 12 mm. long. The best-preserved specimen (Pl. 11, fig. 10) is about 9·5 mm. in length, with a maximum breadth of 8 mm. It is subovate in plan and only moderately convex transversely. There are four pairs of pleural ribs, separated from each other by strong rib furrows which become less well developed from first to fourth. The ribs of the first pair curve abaxially backwards for about half the length of the pygidium and then, more gradually, adaxially. The remaining ribs are subparallel to the first pair but become successively less strongly curved until those of the fourth pair are almost straight, converging backwards subparallel to the axial furrows. The ribs terminate in small, free points which are " stepped " backwards *en echelon* from first to fourth. The axis is in the form of an acute isosceles triangle, the two long sides of which meet posteriorly at about 20 degrees, and there may be up to nineteen, or perhaps twenty, axial rings visible. The first four axial rings are well defined, continuous with the corresponding pairs of ribs. Frontally the axial furrows are present merely as shallow grooves, but they become sharply defined behind the fourth axial ring. Sometimes a fifth axial ring may be defined by a transversely continuous ring furrow, but usually the greater part of the axis bears a smooth median band, occupying about one-third of its breadth, on either side of which the axial rings are clearly defined. There is a small, pointed terminal piece, behind which the points of the fourth pair of ribs extend a little way. The greater part of the surface of the pygidium is smooth but there are traces of incipient tubercles on occasional axial rings, whilst up to five larger tubercles may be found along each rib, particularly its hindmost two-thirds.

Horizons and localities. The earliest-known occurrences of *Atractopyge scabra* within the Cross Fell Inlier are in Dufton Shales belonging to the Onnian Stage at Pus Gill, where the species is uncommon in both the *Onnia gracilis* Zone, locality A 14, and the *Onnia superba* Zone, locality A 5. The new species is more common in

the Pusgillian Stage, at which horizon it is known from Pus Gill, localities A. 25, 27 and 28 ; Swindale Beck, locality B. 25 ; and Dufton Town Sike, localities C. 2, 3 and 5.

HOLOTYPE. BM. In. 50154 (Pl. 11, fig. 2).

PARATYPES. BM. In. 50147 ; In. 50150 (Pl. 11, fig. 3) ; In. 50157 (Pl. 11, fig. 10).

DISCUSSION. The name " *Cybele verrucosa* Dalman ", a species described originally from the Red Tretaspis Shales of Västergötland, Sweden, has often been used in old faunal lists and collections from the Cross Fell Inlier, and from horizons of various ages elsewhere. This trilobite, the type species of *Atractopyge*, has recently been refigured by Henningsmoen (*in* Moore, 1959, fig. 349, 1*a*, *b*) whose illustrations show that it differs markedly from *A. scabra* in having a glabella which is less expanded frontally, with a smaller frontal glabellar lobe, as well as a pygidium which is proportionately shorter, carrying noticeably fewer (15) axial rings, and with the tips of the pleural ribs ending in line posteriorly.

The holotype of *Atractopyge michelli* (Reed, 1914*a* : 42, pl. 7, figs. 7, 7*a–c*) from the Balclatchie Group of Girvan is generally similar to *A. scabra*, but the glabella is less expanded frontally and more coarsely tuberculate, whilst the pygidium is proportionately shorter with fewer, less well-defined axial rings. *Atractopyge scabra* bears a strong resemblance to several forms of the genus said to have been collected from Ashgill strata in the Anglo-Welsh area, but until these have been investigated further it is impossible to say whether the species ranges higher than the Caradoc Series.

The lectotype pygidium of *Atractopyge atractopyge* (M'Coy *in* Sedgwick & M'Coy, 1851, pl. 1G, fig. 4 only ; Dean, 1961*a* : 319), from the Caradoc Series, probably Longvillian Stage, of North Wales, is proportionately broader than that of *A. scabra* and has a less strongly tapered axis, probably with fewer and better-defined axial rings. M'Coy's illustration shows the pleural ribs ending in-line posteriorly, but this is not clear on the actual specimen.

Atractopyge? sp.

(Pl. 11, figs. 5, 8)

1959*a*. *Atractopyge* sp. ind., Dean, p. 214.

A single specimen, a fragmentary cranidium, from the Lower Melmerby Beds, Lower Longvillian Substage, at Alston Road, locality J, figured here in the form of a latex cast, shows features suggestive of *Atractopyge*. The glabella is incomplete but expands forwards and possesses three, almost equisized, pairs of glabellar lobes. The fixigenae stand as high as the glabella, decline steeply towards the axial furrows, and are topped by traces of pedunculate palpebral lobes. The surface of the test is covered with large granules interspersed with larger tubercles, some of which are arranged in pairs symmetrically about the sagittal line. The cranidium is too poorly preserved for comparison with known species, but forms an interesting addition to the trilobites known from the Longvillian Stage of the Anglo-Welsh area. A further specimen (Pl. 11, fig. 5), in a still worse state of preservation, from the Corona Beds, Lower Longvillian Substage, *Bancroftina typa* Zone, at

Harthwaite Sike, locality A. 3, shows only part of a glabella and occipital ring, together with part of the corresponding left fixigena and palpebral lobe. Generic determination is not possible and the specimen is figured here merely as *Atractopyge*? sp., but it may prove to be related to the Alston Road trilobite.

Genus ***PARACYBELOIDES*** Hupé, 1955

TYPE SPECIES. *Cybele loveni* Linnarsson var. *girvanensis* Reed, 1906 by original designation of Hupé (1955 : 271).

Paracybeloides cf. ***girvanensis*** (Reed)

(Pl. 11, figs. 7, 9, 12, 14, 15)

1891. *Cybele Loveni* Linnarsson : Nicholson & Marr, p. 511.
1906. *Cybele loveni* var. *girvanensis* Reed, p. 126, pl. 17, figs. 1–4.
1959*a*. *Paracybeloides* aff. *loveni* (Linnarsson) : Dean, pp. 207, 208.

Numerous specimens of *Paracybeloides* have been collected from the Dufton Shales, and agree in all essential respects with the type material described by Reed (*loc. cit.*) from the Ashgill Series of Girvan. According to Reed's original description the pygidial axis carries twenty-two to twenty-eight axial rings, but examination of several specimens, including syntypes, in the Gray Collection at the British Museum (Nat. Hist.) suggests that the average number of rings present is about twenty-three, whilst specimens with twenty or twenty-one rings are not unknown. The variation in the number of axial rings found on the Cross Fell specimens is from twenty to twenty-three, the most common number being twenty-one, and this slight difference is not considered here to be of sufficient importance for specific differentiation.

The tip of the pygidium of *P. girvanensis* was inaccurately illustrated by Reed (*loc. cit.*), who has been followed by other workers, for example Hupé (1955 : 272) and Henningsmoen (*in* Moore, 1959, fig. 349, 5*b*). Reed's illustration shows the terminal piece of the pygidial axis ending in front of the hindmost pair of pleural points which, according to him, were separated from each other by a small gap. In fact, the specimens figured by him, including BM. In. 23243 (Reed, 1906, pl. 17, fig. 4), possess a terminal piece which is produced postaxially into a long, flattened, pointed process, constituting the longest (*sag.*) portion of the pygidium and united abaxially with the proximal pair of pleural points so as to form a flattened, trifid, pygidial termination. One of the Cross Fell specimens, BM. In. 50178, shows that the terminal process described above was sometimes produced to an even greater degree, giving a slender, pointed spine ; the total length of this particular pygidium is approximately 17 mm., of which the axis *sensu stricto* occupies only about 10 mm.

Reed's illustrations of the cephalon of *P. girvanensis* show also that it possesses a smooth occipital ring. This is apparently the case in the syntypes, and also in other specimens, when preserved as internal moulds, but it is clear from the corresponding external moulds that they, together with the Cross Fell specimens,

have a large median tubercle which may occasionally be produced backwards and upwards to form a blunt, occipital spine.

HORIZON AND LOCALITIES. *Paracybeloides* cf. *girvanensis* appears uncommonly in the Onnian Stage, *Onnia gracilis* Zone, of Pus Gill, locality A.5, but has not yet been recorded from the overlying *Onnia superba* Zone ; this apparent absence may be due to the paucity of exposures of the relevant strata. In the Pusgillian Stage the same species becomes more abundant and has been found at Pus Gill, localities A. 18, 25, 28–30 ; Swindale Beck, locality B. 25 ; and Dufton Town Sike, locality C. 2.

Paracybeloides sp.

(Pl. 11, fig. 11)

1959*a*. *Paracybeloides* sp. ind., Dean, p. 214.

One specimen only has been found in the Longvillian Stage, constituting the sole record of the genus at this horizon in the Anglo-Welsh area. It comprises a pygidium which, excluding spines, is about 5 mm. in length with a frontal breadth of about 4 mm. The axis is narrow, less than one-third the frontal breadth, and carries an estimated eighteen axial rings. Although the specimen is damaged, most of the axial rings can be seen to be obsolete medially, where a median band extends backwards from at least the fourth ring. The main body of the axis is relatively short, just over two-thirds of the total length of the specimen, but the terminal piece is long, slender, and produced backwards, though the tip is not visible. The pleural lobes are imperfectly preserved but appear to be of generally similar form to those of *Paracybeloides girvanensis*. The specimen is inadequate for detailed comparison with other species, but appears to be smaller and more slender than the pygidium of *P. girvanensis*, with fewer axial rings. It bears some resemblance to the specimen of *Paracybeloides* figured by Whittington & Williams (1955, pl. 40, fig. 110 only) as *Atractopyge* sp. ind., from the Derfel Limestone of early Caradoc age.

HORIZON AND LOCALITY. Lower Melmerby Beds, Lower Longvillian Substage, Alston Road, locality J (see Text-fig. 5).

Family DALMANITIDAE Reed, 1905

Subfamily DALMANITINAE Reed, 1905

Genus ***DALMANITINA*** Reed, 1905

TYPE SPECIES. *Dalmania socialis* Barrande, 1852 by original designation of Reed (1905*a* : 224).

Dalmanitina mucronata (Brongniart) ***matutina*** subsp. nov.

(Pl. 12, figs. 1, 5, 6, 9, 12)

1959*a*. *Dalmanitina* sp. nov., Dean, pp. 204, 208.

DIAGNOSIS. Subspecies of *Dalmanitina mucronata* (Brongniart), characterized by smaller fixigenal spines ; palpebral lobes developed from opposite mid-points of first glabellar lobes to corresponding position opposite third glabellar lobes ;

pygidium, excluding terminal spine, broader than long, with eight axial rings and seven pleurae.

DESCRIPTION. *Dalmanitina mucronata* (Brongniart) has been figured and described in detail by Temple (1952). The cephalon of the new subspecies resembles that of *D. mucronata* in all save two respects. The more important of these is the length of the palpebral lobes which, in *D. mucronata matutina*, extend from just outside the axial furrows, slightly in front of the mid-points of the first glabellar lobes, backwards and slightly outwards until almost opposite the mid-points of the third glabellar lobes. In *D. mucronata* itself the palpebral lobes extend backwards from the first glabellar furrows until level with, or slightly behind, the second glabellar furrows. Only one specimen of the new subspecies has been found with part of the fixigenal spine preserved, but the latter appears to be smaller than that of *D. mucronata*.

The hypostoma and thorax are not known.

The pygidium is subparabolic in outline, broader than long. The most complete specimen, excluding the articulating half-ring and terminal spine, is 18 mm. broad and about 11 mm. (estimated) long. The axis occupies just over one-quarter of the frontal breadth, about four-fifths of the median length (excluding terminal spine), and is bounded by straight axial furrows which converge backwards and die out alongside the terminal piece. There are eight axial rings, the first three of equal length (*sag.*), the remainder becoming successively shorter. The articulating furrow and the three succeeding ring furrows are moderately broad (*sag.*) and fairly shallow medially, but become narrow abaxially and deepen to form apodemal pits. The remaining ring furrows are of more uniform depth but become shallower from the fourth furrow onwards, and the seventh and eighth furrows do not quite attain the axial furrows on the internal mould. The terminal piece is subtriangular in plan and passes backwards into a well-developed, post-axial ridge which runs, in turn, into a stout, upturned, terminal spine. The pleural lobes are gently convex dorsally, ending abaxially in smooth margins where there is a narrow doublure of apparently uniform breadth. Each lobe carries seven pleurae, the first three of which are separated by faintly-impressed, interpleural furrows and ornamented by deep, pleural furrows which curve gently and abaxially backwards. The remaining pleural and interpleural furrows are of about equal depth but become slightly less impressed towards the tip of the pygidium. On the internal mould all these furrows end abruptly at the proximal margin of the doublure, but on the external mould they may be traced, in a much attenuated condition, to the lateral margin, coincident with a poorly-defined border. The test of the entire pygidium, including the terminal spine, is smooth.

Apart from having a smaller number of axial rings than the pygidium of *D. mucronata*, eight as compared with eleven, that of the new subspecies differs also in being relatively broader, almost semicircular in outline, with fewer pleurae, seven compared with eight or nine, whilst the terminal spine is stouter and perhaps longer.

HORIZON AND LOCALITIES. Most of the type-specimens are from Dufton Shales near the top of the Pusgillian Stage in Swindale Beck, locality B. 25. One of the paratypes, however, is from Pus Gill, locality A. 7, where the horizon is low in the

Pusgillian, not far above its presumed junction with the underlying Onnian Stage. Another specimen has been collected by Mr. M. Mitchell from Pusgillian strata in the section at Hurning Lane, 700 yards north-east of St. Cuthbert's Church, Dufton.

Holotype. BM. In. 49915 (Pl. 12, fig. 6).

Paratypes. BM. In. 50112 (Pl. 12, fig. 1); In. 50113 (Pl. 12, fig. 5); In. 49919 (Pl. 12, fig. 9); In. 50114 (Pl. 12, fig. 12).

Subfamily Acastinae Delo, 1935

Genus ***KLOUCEKIA*** Delo, 1935

Type species. *Phacops phillipsi* Barrande, 1846 by original designation of Delo (1935 : 408).

Subgenus ***Phacopidina*** Bancroft, 1949

Type species. *Phacopidina harnagensis* by original designation of Bancroft (1949 : 310).

Kloucekia (Phacopidina) apiculata (M'Coy)

(Pl. 12, fig. 11)

1851. *Portlockia* ? *apiculata* M'Coy *in* Sedgwick & M'Coy, p. 162.
1910. *Phacops apiculatus* Salter : Reed, p. 211.
1961*a*. *Kloucekia* (*Phacopidina*) *apiculata* (M'Coy) Dean, p. 324, pl. 2, figs. 6–9, 12. Includes full synonymy of the species.

Several specimens of this characteristic middle Caradoc trilobite have been found in the vicinity of the Alston Road, north-east of Melmerby. The remains are usually fragmentary but may sometimes include articulated thoracic segments. The material agrees closely with the descriptions given by Harper (1947 : 169) and later by Dean (1961*a* : 324), but the individuals, which occur in ashy mudstones, are somewhat smaller than typical North Welsh specimens and significantly smaller than those from south Shropshire, perhaps the result of a less favourable environment.

Horizons and localities. *Kloucekia apiculata* has been collected from the Lower Melmerby Beds, Lower Longvillian Substage, of the Alston Road outcrop (see Text-fig. 5) at localities B, C, E, F, G and J, and from the Upper Melmerby Beds, Upper Longvillian Substage, of the same section at locality H. The species has been found nowhere else in the Cross Fell Inlier.

Genus ***DUFTONIA*** Dean, 1959

Type species. *Duftonia lacunosa* by original designation of Dean (1959 : 143).

Duftonia lacunosa Dean

(Pl. 12, fig. 3)

1948. *Pterygometopus* sp., Bancroft *in* Lamont, p. 468.
1959. *Duftonia lacunosa* Dean, p. 144, pl. 19, figs. 1–3, 5, 6, 8.
1959*a*. *Duftonia lacunosa* Dean : Dean, pp. 203, 204, 208.

The species has already been described in detail. All the type-specimens are from the uppermost part of the Dufton Shales, Pusgillian Stage, at Swindale Beck, locality B. 25, but other specimens have been found, though less commonly, at locality B. 24 ; in Pus Gill, locality A. 22 ; and at Hurning Lane, north of Dufton. At both the latter localities the horizon is apparently somewhat lower in the Pusgillian than are the rocks of the type-locality.

HOLOTYPE. BM. In. 49824 (Pl. 12, fig. 3).

PARATYPES. BM. In. 49821 ; In. 49826 ; In. 49830 ; In. 49920.

Family PTERYGOMETOPIDAE Reed, 1905

Subfamily PTERYGOMETOPINAE Reed, 1905

Genus ***CALYPTAULAX*** Cooper, 1930

TYPE SPECIES. *Calyptaulax glabella* by original designation of Cooper (1930 : 387).

Calyptaulax planiformis sp. nov.

(Pl. 13, figs. 1–5)

1891. *Phacops brongniarti* Portlock, Nicholson & Marr, p. 505.
?1945. *Calyptaulax* sp., Størmer, p. 418, pl. 4, fig. 10.
1959*a*. *Calyptaulax* aff. *norvegicus* Størmer : Dean, pp. 204, 208.

DIAGNOSIS. Glabella slightly longer than broad, pentagonal in outline, bluntly pointed frontally attaining maximum breadth across frontal globe. Three pairs of glabellar lobes ; first and second pairs conjunct laterally, third lobes small, almost separated from remainder of glabella. Eyes long, crescentic in plan, extending from opposite first glabellar lobes almost to pleuroccipital furrow. Pygidium subtriangular in plan, broader than long, with large facets, and terminates in blunt point. Tapering axis with seven to ten axial rings ; pleural lobes with six pleural furrows.

DESCRIPTION. Entire cephalon unknown. The glabella is only slightly convex, even in uncrushed specimens, pentagonal in outline, broadly pointed frontally, the length, excluding occipital ring, being slightly greater than the maximum breadth. The frontal lobe is alate, extending laterally as far as the anterior ends of the first glabellar lobes ; there it meets the axial furrows, which diverge forwards at about 30 degrees. The first glabellar furrows are only moderately deep, slightly sigmoidal, and widely divergent anteriorly ; the first glabellar lobes are long and trapezoidal in outline. The second glabellar furrows are shallow, curved, convex forwards, and directed slightly backwards, not reaching the axial furrows, so that the distal ends of the first glabellar lobes are continuous with the smaller, backwardly-directed, second glabellar lobes. The third glabellar furrows are deep, with apodemes, diverge backwards and almost isolate the third glabellar lobes which are thus present only as semi-detached tubercles at the distal ends of the basal glabellar segment. The occipital ring is long (*sag.*), especially medially, moderately broad, and convex forwards with occipital lobes developed abaxially ; it is separated from the glabella

by the occipital furrow which is shallow medially but deepens laterally, where it is indented by the third glabellar lobes. The fixigenae are broad and level with long, crescentic, palpebral lobes which are separated from the cheeks by conspicuous palpebral furrows extending from the front of the first glabellar lobes to the pleuroccipital furrow. The pleuroccipital segment is preserved in only one specimen (Pl. 13, fig. 2) ; the pleuroccipital furrow becomes shallower laterally, not reaching the lateral margin, and the genal angle is rounded. The anterior branches of the facial suture follow the outline of the glabella and no preglabellar furrow is developed, whilst the posterior branches curve gently forwards from behind the palpebral lobes before curving backwards to meet the lateral margins.

The hypostoma and thorax are unknown.

The pygidium is roughly triangular in outline, the length approximately two-thirds the breadth, with gently convex lateral margins which taper posteriorly to a blunt, slightly upturned point. The axis tapers backwards fairly sharply and carries seven to ten axial rings which diminish posteriorly in size and in degree of definition. Beyond the tip of the axis there is a low, postaxial ridge. The pleural lobes are only moderately convex and carry six pleural furrows which decrease in depth from first to sixth, extend just over half-way from the axial furrows to the lateral margin, and become progressively less divergent backwards. The first pleural furrows are truncated distally by a pair of large facets. The first rib furrows are deep, extending rather more than half the breadth of the pleural lobes to cut the lateral margins, and are directed sharply backwards laterally. Subsequent rib furrows are only faintly impressed, though about three can usually be traced at the margin.

Horizons and localities. In the Cross Fell Inlier *Calyptaulax planiformis* appears in small numbers in the *Onnia gracilis* Zone of the Onnian Stage, has not yet been found in the *Onnia superba* Zone, probably as the result of inadequate exposures, and becomes more common in the Pusgillian. Most of the type specimens are from the Pusgillian at Swindale Beck, locality B 25, but one paratype is from the *Onnia gracilis* Zone at Pus Gill, locality A. 12. Another locality where the species is known to occur is Pus Gill, locality A. 6, also in the Pusgillian Stage.

Holotype. BM. In. 50138 (Pl. 13, fig. 4).

Paratypes. BM. In. 49903 (Pl. 13, fig. 3) ; In. 49907 (Pl. 13, fig. 5) ; In. 49908 (Pl. 13, fig. 2) ; In. 49965 (Pl. 13, fig. 1).

Discussion. *Calyptaulax planiformis* is clearly related to the approximately contemporaneous *C. norvegicus* Størmer (1945 : 417, pl. 4, figs. 2, 3), a species which may possibly be synonymous with *Calyptaulax* [*Homalops*] *altumi* (Remelé) figured by Wiman (1908, pl. 8, figs. 7–10) from the Baltic region. *C. planiformis* differs from *C. norvegicus* in the following respects : the glabella is proportionately longer and less rounded frontally ; the axis of the pygidium is longer ; the rib furrows are definitely, though generally faintly, defined at the pygidial border, contrasting with the smooth border described by Størmer (1945 : 418). In the last feature the Cross Fell species resembles more the pygidium figured by Størmer (1945, pl. 4, fig. 10) as *Calyptaulax* sp.

Although *Calyptaulax* was once thought to be a predominantly North American genus it is now known from several places in northern Europe and Scandinavia.

In addition to the Norwegian and Baltic records mentioned above, Jaanusson (1953 : 102–103) has recorded *Homalops* (= *Calyptaulax*) cf. *altumi* Remelé from the Slandrom Limestone, *Pleurograptus linearis* Zone, of southern Sweden.

Calyptaulax actonensis Dean (1961*a* : 328) from the Actonian and basal Onnian Stages of south Shropshire strongly resembles the new species, particularly in the form of the cranidium, but the pygidium is slightly shorter, has a shorter axis with fewer axial rings, possesses more strongly defined pleural furrows, and terminates in a better-developed, pointed, caudal spine.

Of the other comparable species of the genus, *Calyptaulax compressa* (Cooper, 1930, pl. 5, figs. 7, 8) has a shorter glabella and smaller fixigenae than has *C. planiformis*, and the pygidium of *C. glabella* (Cooper, 1930, pl. 5, figs. 9–11) is both broader and more pointed posteriorly. *Calyptaulax schucherti* from the Cape Calhoun Formation of northern Greenland (Troedsson, 1929, pl. 19, figs. 17–20) may be distinguished from the new species by its shorter frontal glabellar lobe, and smaller fixigenae and first glabellar lobes.

Genus ***ESTONIOPS*** Männil, 1957

Estoniops comprises phacopid trilobites generally resembling *Pterygometopus* (*s.s.*) but differing essentially from that genus in their lack of a preglabellar furrow. The frontal lobe of the glabella is large and broad, and the first glabellar lobes are relatively large, but the second and third glabellar lobes are much reduced in size. The genal angles are rounded. The surface of the glabella is covered with coarse tubercles, but that of the cheeks is pitted. The pygidium is generally similar to that of *Pterygometopus*, the tip being bluntly rounded, and has a smooth border.

Estoniops has been found in Britain only in the Upper Longvillian Substage of the Anglo-Welsh area but the genus is widely distributed geographically and is known from Scandinavia and the Baltic region. These extra-British occurrences appear to be roughly contemporaneous with, or somewhat earlier than, the Anglo-Welsh material.

Type species. *Acaste exilis* Eichwald, 1857 by original designation of Männil (1957 : 386).

Estoniops alifrons (M'Coy)

(Pl. 12, figs. 2, 4, 7, 8, 10, 13, 14)

1851. *Phacops* (*Phacops*) *alifrons* M'Coy *in* Sedgwick & M'Coy, p. 159, pl. 1G, figs. 12–14.
1852. *Phacops* (*Phacops*) *alifrons* M'Coy : Salter, p. *ii*.
1853. *Phacops jukesi* Salter, p. 11.
1864. *Phacops* (*Acaste*) *alifrons* M'Coy : Salter, p. 33, pl. 1, figs. 31–34.
1864. *Phacops* (*Chasmops* ?) *jukesii* Salter : Salter, p. 36, pl. 1, figs. 29, 30.
1873. *Phacops* (*Acaste*) *alifrons* M'Coy : Salter, p. 52.
1891. *Phacops* (*Acaste*) *alifrons* M'Coy : Woods, p. 149.
1922. *Pterygometopus jukesii* (Salter) Elles, pp. 150, 152, 170.
1923. *Phacops* (*Pterygometopus*) *jukesii* Salter : King, p. 491.
1933. *Pterygometopus jukesi* (Salter) : Bancroft, table 1.
1945. *Phacops* (*Calliops*) *jukesi* Salter : Reed, p. 315.

1959. *Estoniops jukesi* (Salter) Dean, p. 146.
1959*a*. *Estoniops jukesi* (Salter) : Dean, pp. 194, 207, 220.
1951*a*. *Estoniops alifrons* (M'Coy) Dean, p. 320.

The species was founded by M'Coy (*in* Sedgwick & M'Coy, 1851 : 159) on three syntypes, now in the Sedgwick Museum. One of these, numbered A. 42694 (Sedgwick & M'Coy, 1851, pl. 1G, fig. 12), is chosen here as lectotype and is re-figured (Pl. 12, fig. 4). It comprises a damaged, incomplete cephalon which has undergone slight lateral compression, so that the glabella appears more elongated than is normally the case. The specimen was said to be " from the impure limestone of Capel Garmon " (Denbighshire), a horizon presumed to be of Upper Longvillian age. The remaining syntypes comprise two pygidia, said to be from the " Limestone of Pont y Glyn, Diffwys " (Denbighshire). One of them, Sedg. Mus. A. 42695 (Sedgwick & M'Coy, 1851, pl. 1G, fig. 13), is incomplete and probably slightly crushed, whilst the other, A. 42696 (Sedgwick & M'Coy, 1851, pl. 1G, fig. 14), is a complete pygidium, preserved as an internal mould which is believed to have undergone slight longitudinal compression and is therefore thought to be unsuitable for systematic description owing to the exaggeration of the pleural furrows.

Phacops jukesi Salter (1853 : 11), a species regarded here as a synonym of *Estoniops alifrons*, was established using two syntype cephala from the Bala district. These are in the Geological Survey & Museum where they are numbered 19165 and 19166.

Owing to the poor state of preservation of the type specimens of *Estoniops alifrons* the following description is founded also on supplementary material from both the Bala district, north Wales, and the Cross Fell Inlier.

Description. The cephalon is strongly convex, of semi-elliptical form, broader than long. The glabellar outline is slightly convergent from the posterior border as far as the outer ends of the second glabellar furrows, but then expands rapidly forwards, attaining its maximum breadth a short distance in front of the first glabellar furrows. The glabella is slightly broader than long and there is no preglabellar furrow. The frontal lobe is convex, strongly alate, its projected length in an uncrushed specimen being about two-fifths that of the glabella. The first glabellar furrows are moderately deep, directed backwards slightly and extending adaxially about one-quarter to one-third of the glabellar breadth. The second glabellar furrows are deep, short (*tr.*), directed forwards slightly so that the first glabellar lobes are almost subtriangular in outline. The second glabellar lobes are small, directed backwards, bounded posteriorly by deep third glabellar furrows. The third glabellar lobes are merely the swollen ends of what may be described as a ring-like segment, corresponding in position with the occiput or peduncle of the Trinucleidae and separated by a well-defined occipital furrow from the convex occipital ring, which is slightly wider (*tr.*) than is the glabella across the basal lobes. The axial furrows are narrow and deep, becoming shallower opposite the first glabellar lobes, with hypostomal pits situated opposite the first glabellar furrows. From the posterior margin as far as the second glabellar lobes, the axial furrows converge slightly but then diverge markedly until just beyond the first glabellar furrows, whence they coalesce with the lateral marginal furrows ; the latter run back as far as the distal ends of the pleuroccipital furrow, towards which they become consider-

ably shallower. The eyes are prominent, standing as high as, or slightly higher than, the glabella, and the fixigenae are declined steeply towards the axial furrows. The eye of one of the Cross Fell specimens contains about 165 lenses arranged in twenty-four vertical rows, each row containing from four to eight lenses, but Welsh specimens have not yet been found sufficiently well preserved for detailed comparison. The palpebral lobes are sharply crescentic in form, bounded by deep palpebral furrows. Each palpebral furrow runs from the axial furrow and turns sharply through a right angle opposite the mid-point of the eye before attaining the posterior end of the latter ; from this point a deep furrow runs immediately below the eye, whilst another furrow curves gently forwards and then laterally backwards, becoming almost obsolete before intersecting the lateral marginal furrow. The anterior branches of the facial suture run obliquely forwards from the eyes to cut the axial furrows just in front of the hypostomal pits ; they then turn sharply inwards to converge and meet in front of the glabella. The posterior branches curve forwards gently from behind the eyes and then straighten before cutting the lateral margins ; they are situated in the furrows already described. The librigenae are fused frontally, and a median suture is not developed. The pleuroccipital furrows are deep and transversely straight but die out before reaching the margin. The pleuroccipital segment widens (*exsag.*) noticeably towards the smoothly rounded genal angles. The test of the glabella is covered with coarse tubercles the surface of which, together with the intervening area, is finely granulate. The surface of the cheeks is pitted, but that of the palpebral lobes, occipital ring, pleuroccipital segment and cephalic border is smooth or finely granulate. The cephalic doublure is similarly ornamented but there is no sharp demarcation between this and the tuberculate upper surface of the cephalon at the line of the facial suture.

The hypostoma and thorax are unknown.

No well-preserved topotype pygidium being yet available for examination, the following description is founded on a pygidium, presumed to belong to the species (Pl. 12, figs. 8, 10), which has been found at Swindale Beck in association with a cephalon of *E. alifrons*. The outline is broadly semi-elliptical, the anterior margin slightly convex forwards, and the tip well rounded. The straight-sided, tapering axis, bounded by deep axial furrows, has seven, well-defined axial rings, followed by two further rings which are less distinct medially. The pleural lobes carry six ribs, separated by deep furrows, with a seventh rib less well defined. Interpleural furrows are only faintly impressed and neither they nor the pleural furrows attain the lateral margin, so that a smooth border results.

Horizon and localities. Although the horizon of M'Coy's syntypes was not specifically stated, the evidence of all other known occurrences of *Estoniops alifrons* in the Anglo-Welsh area suggests that they must have been collected from strata of Upper Longvillian age. Salter's type material of *Phacops jukesi* in the Geological Survey & Museum is labelled merely " Caradoc " of Gelli Grin, Bala, but all the material of the species from that area contained in the Bancroft Collection at the British Museum (Nat. Hist.) is described as having been collected from the Upper Longvillian substage, presumably from what Bancroft (1933, table 1) termed the *Pterygometopus jukesi* Beds. In her paper on the Bala district Elles (1922 : 150,

152, 170) recorded *Pterygometopus jukesi* from the Gelli Grin Calcareous Ash Series at various localities near Bala. The rocks in which *E. alifrons* occurs at Cross Fell belong to the upper half of the Upper Longvillian substage. The species is uncommon there and has, as yet, been found at only two localities, both in Swindale Beck, B. 7 and B. 10.

Phacops (*Pterygometopsis*) [*sic*] cf. *jukesi* has been recorded from the Pen-y-garnedd Limestone of the Berwyn Hills, North Wales (Wedd *et al.*, 1929 : 44), a horizon now known to contain Upper Longvillian fossils (Whittington, 1938 : 436, 451).

LECTOTYPE, here selected. Sedgwick Mus. A. 42694 (Pl. 12, fig. 4).

PARATYPES. Sedgwick Mus. A. 42695 ; A. 42696.

DISCUSSION. In redescribing the holotype of the type species of *Pterygometopus*, *P. sclerops* (Dalman), Whittington (1950 : 548) sought to restrict the genus to that species and *P. trigonocephala* (Schmidt) on account of their having such features as a distinct preglabellar furrow, set back slightly from the facial suture in front of the glabella, and palpebral furrows which continue behind the eye and then, containing the posterior branches of the facial suture, curve towards the marginal furrows. Other forms usually assigned to *Pterygometopus* were said to be distinct because the preglabellar furrow was not impressed, the glabella and preglabellar field being continuous, and the genus *Estoniops* seems to accommodate these phacopids.

Estoniops shares certain characteristics, such as the absence of a preglabellar furrow and the presence of cheeks with a pitted surface, with the genus *Duftonia* (Dean, 1959) but, in addition to other features, the possession of fixigenal spines and a mucronate pygidium assist in separating the latter generically. *Estoniops alifrons* has many features in common with *E. exilis* Eichwald sp. (Schmidt, 1881 : 86, pl. 1, figs. 18–21 ; pl. 12, fig. 13 ; Wigand, 1888 : 43, pl. 6, figs. 5*a*, *b*) from the Kuckers Shale, Stage C2, of Estonia, a horizon probably slightly earlier in age than the Upper Longvillian, but the cephalon of the British form differs in having a more elongate glabella and more divergent axial furrows. A particularly noticeable feature in both species, and in others assigned to *Estoniops*, is the curiously angular form of the palpebral furrow, that of *E. exilis* having been illustrated by Öpik (1937 : 163, fig. 42). *Phacops* (*Pterygometopus*) *panderi* Schmidt (1881 : 84, pl. 1, figs. 15–17 ; pl. 12, figs. 10–12) from Stage C1 of the Baltic region bears some resemblance to *Estoniops* but differs in having tuberculate cheeks, and it is not known whether this feature is of more than specific significance.

Two specimens figured by *Salter* (1864, pl. 1, figs. 33, 34) as *Phacops* (*Acaste*) *alifrons* can probably be assigned to that species. One of them, GSM 19109 (*Salter*, 1864, pl. 1, fig. 35) is an incomplete cephalon labelled, on the tablet, " Tyn-y-cabled, Pennant " ; the other, GSM 19107, is a somewhat distorted pygidium from " Goetre, Meifod ". The latter, from its general similarity to the Swindale Beck pygidium figured here, almost certainly belongs to the same species and is associated with a cephalon, GSM 19108, which definitely belongs to *E. alifrons*. None of the localities above matches those listed by Salter (1864 : 34) for *Phacops alifrons*.

The specimen recorded in the Oswestry Memoir (Wedd *et* al., 1929 : 61) as *Phacops* cf. *alifrons* from the Ashgill Series of the Berwyn Hills is, in fact, a crushed *Paracybeloides* sp. ; it is numbered RE 938–9 in the Geological Survey & Museum.

The trilobite from the Balclatchie Beds of the Girvan district described by Reed (1945 : 314, pl. 1, fig. 6) as *Phacops* (*Calliops*) *jukesi* var. *vicina* appears to be a typical *Calliops* not unlike *C. brongniarti* (Portlock) and cannot be considered closely related to *Estoniops alifrons*.

Subfamily Chasmopsinae Pillet, 1953

Genus ***CHASMOPS*** M'Coy, 1849

Type species. *Calymene odini* Eichwald, 1840 by original designation of M'Coy (1849 : 403).

Chasmops cf. ***extensa*** (Boeck)

(Pl. 13, fig. 8)

1959*a*. *Chasmops* cf. *extensa* (Boeck) : Dean, p. 207.

Three fragmentary pygidia belonging to *Chasmops* of the *extensa* species-group have been recovered from Swindale Beck, but only one is sufficiently well preserved for descriptive purposes. The specimen is about 18 mm. long, and the original maximum breadth is estimated to have been about 27 mm. The axis is narrow, with a frontal breadth of about 5 mm., tapers strongly backwards and ends about 3·5 mm. in front of the tip of the pygidium. There is evidence, obscured by crushing, of a postacial ridge. As far as the state of preservation allows, there appear to be fifteen axial rings. Each pleural lobe carries fourteen ribs, the pleural furrows becoming noticeably shallower near the lateral margin. Each rib usually bears a faintly-impressed interpleural furrow and becomes wider (*exsag.*) abaxially. The ribs become smaller towards the tip of the pygidium, at the same time changing their position relative to the axis until the smallest are almost parallel to the sagittal line.

Horizon and locality. Dufton Shales, believed to belong to the middle portion of the Actonian Stage, at Swindale Beck, locality B. 15. The associated fauna includes *Onnicalymene*, *Remopleurides* and *Onniella*.

Discussion. *Chasmops extensa* has been redescribed by Størmer (1940 : 138, pl. 3, figs. 7–11) whose illustrations of the pygidium show that it possesses fifteen axial rings and fourteen pleural ribs, corresponding with the numbers in the specimen now figured. The type pygidium is, however, much more elongate, and narrowly elliptical in outline, but the specimen is uncrushed whereas those from Cross Fell are flattened in a dark-grey shale. In southern Norway *C. extensa* is characteristic of the Upper Chasmops Shale and Limestone, and in south Shropshire members of the same species are most abundant in the Actonian and Marshbrookian Stages, though appearing earlier, in the Upper Longvillian, and ranging upwards into the lowest part of the Onnian (Dean, 1961*a* : 335).

Chasmops aff. *maxima* (Schmidt)

(Pl. 13, fig. 6)

1959*a*. *Chasmops* aff. *maxima* (Schmidt) : Dean, p. 208.

The material consists only of one damaged cranidium, estimated length about 15 mm. It is moderately convex, both longitudinally and transversely, and the axial furrows diverge anteriorly at approximately 40 degrees. The frontal lobe is incomplete but its length is about two-thirds of the estimated breadth. The first glabellar furrows are almost straight, diverging forwards at 110 degrees and deepening towards the axial furrows ; the first glabellar lobes are triangular in outline, their convexity conforming with the remainder of the glabella. The second glabellar furrows converge forwards at about 75 degrees and deepen markedly towards the axial furrows ; the second glabellar lobes are present only as small tubercles. The third glabellar furrows occur as notches separating the second glabellar lobes from those of the third pair, which are represented by tubercle-like projections situated just behind the first glabellar lobes and slightly overlapping the occipital furrow. The latter is transversely straight, deepening towards the axial furrows, near which it contains a pair of apodemal pits. Another pair of apodemal pits is situated at the hind margin of the occipital ring, just inwards from the axial furrows and bordering two small, anteriorly-projecting, occipital lobes. The pleuroccipital furrow is moderately deep and the pleuroccipital segment is fairly narrow (*exsag.*), but the two are only partly preserved. Even though incompletely preserved, the one surviving palpebral lobe is prominent, raised above the level of the glabella and carries a shallow, palpebral furrow. In plan the palpebral lobe extends from a point almost opposite the middle of the first glabellar lobe to one opposite the third glabellar lobe. The fixigena declines steeply from the palpebral lobe to the axial furrow.

Horizon and locality. Dufton Shales in, probably, the higher part of the Pusgillian Stage at Pus Gill, locality A. 28.

Discussion. The species has been discussed in detail by Størmer (1945 : 420) who has pointed out that Schmidt (1881 : 112) founded *C. maxima* on specimens from both the Jewe and Kegel Stages and figured a variety of forms under the one name. The specimen from Pus Gill matches best the specimens of *C. maxima* figured by Størmer from the Tretaspis Shales of Hadeland, though a detailed comparison is not possible with the material available.

Chasmops sp.

(Pl. 13, fig. 12)

1959*a*. *Chasmops* sp., Dean, p. 214.

Two specimens of *Chasmops* have been recovered from the Caradoc Series near Melmerby. One, a cranidium BM. In. 54655, is too badly damaged for detailed examination. The other, an almost complete pygidium In. 54656, is slightly distorted, but the length and breadth are estimated to have been respectively 12 mm. and about 16 mm. The axis possesses eleven axial rings extending almost to

the terminal piece which, although damaged, appears to be only partly differentiated from the postaxial ridge. The pleural lobes have ten, or perhaps eleven, ribs some of which bear faint traces of interpleural furrows. The ribs are separated from one another by deep pleural furrows which, as far as can be ascertained, extend to the lateral margins of the pygidium.

Horizon and locality. Lower Melmerby Beds, probably representing as an yet undetermined part of the Lower Longvillian Substage, at the Alston Road section near Melmerby, locality J (see Text-fig. 5).

Discussion. The fragmentary evidence available suggests that the species may be new. It is certainly distinct from the so-called longicaudate forms of *Chasmops*, such as *C. extensa* (Boeck), which are so abundant higher in the Caradoc Series of Shropshire and Norway, and its affinities are more likely to lie with the group typified by *Chasmops conicophthalma* (Sars & Boeck), a species redescribed by Størmer (1940 : 137, pl. 3, figs. 1–6) and characteristic of part of the Caradoc Series in Norway prior to the appearance of *C. extensa*.

Family Homalonotidae Chapman, 1890

Genus ***BRONGNIARTELLA*** Reed, 1918

Type species. *Homalonotus bisulcatus* M'Coy, 1851 by original designation of Reed (1918 : 322).

Brongniartella minor (Salter)

(Pl. 15, fig. 4 ; Pl. 16, fig. 11)

1852. *Homalonotus bisulcatus* var. *β minor* Salter, p. *v*.
1947. *Brongniartella parva* Harper, p. 165, pl. 6, figs. 7, 8.
1961*a*. *Brongniartella minor* (Salter) Dean, p. 351, pl. 54, fig. 6 ; pl. 55, fig. 11.

A few specimens found at one locality in the Inlier agree in all respects with Salter's species, the lectotype of which, a pygidium, was originally described from the Longvillian Stage of the Bala district, North Wales. Although the outer surface of the test, when preserved, is apparently smooth, internal moulds show a conspicuous granulation due to the infilling of small canals within the test. A similar feature is found in *Brongniartella ascripta* (Reed), described elsewhere in this paper.

Horizon and locality. Upper part of the Corona Beds, Lower Longvillian Substage, *Bancroftina typa* Zone, at Pus Gill, locality A. 3 and Harthwaite Sike, E.3.

Brongniartella ascripta (Reed)

(Pl. 15, figs. 1, 2, 5, 8, 11 ; Pl. 16, fig. 14?)

1910. *Homalonotus ascriptus* Reed, p. 216, pl. 17, figs. 4–8.
1918. *Homalonotus ascriptus* Reed : Reed, p. 272.
1959*a*. *Brongniartella ascripta* (Reed) Dean, p. 214.

Reed's description was founded on a single cranidium, which may be taken as the holotype, supplemented by three additional cranidia and a hypostoma, all

of which he regarded only as belonging doubtfully to the species. There seems to be little doubt that these specimens belong to *B. ascripta*. The holotype cranidium is somewhat flattened but retains, nevertheless, a longitudinal, median ridge which is particularly well shown on the anterior half of the glabella. In the same specimen crushing has produced what appear to be large, basal glabellar lobes, but all the uncrushed specimens available show no trace of glabellar furrows. Reed described the test of the cranidium as being covered with closely-set " tubercles ", and considered this feature sufficient to distinguish the species from *Brongniartella bisulcata*, but examination of additional material suggests that the so-called tubercles are, in fact, infillings of canals within the original test, the outer surface of which was probably smooth. The straight lateral and frontal margins of the glabella, with the fairly well-defined anterior border and the median carina, suggest that *B. ascripta* may be grouped with forms such as *Brongniartella minor* (Salter) and *B. minor subcarinata* Dean, rather than with *B. bisulcata* and *B. caradociana* (Dean, 1961*a* : 349). The presumed hypostoma of *B. ascripta* is quite distinct from that of *B. bisulcata* (see Dean, 1961*a*, pl. 54, fig. 9), and such a difference may eventually prove to be of subgeneric, or even generic, significance. The thorax is known only from isolated segments which are not distinguishable from those of *B. bisculata*. The presumed type-locality has yielded a few pygidia believed to belong to the species. The largest and most complete of these, BM. In. 52980, is slightly distorted and has a median length of about 17 mm. The pleural lobes are well segmented with seven, and perhaps eight pairs of pleural furrows, the first pair being noticeably deeper than the rest ; the furrows extend to the lateral margin, near which they become shallower and almost obsolete. The axis of this specimen is not sufficiently well preserved for an accurate assessment of the number of axial rings, but another, incomplete pygidium shows that there are at least seven, and probably more.

Horizon and localities. It is believed that Reed's original material was obtained from locality J near the Alston Road, north-east of Melmerby; the rocks there are thought to belong to the Lower Melmerby Beds, of probable Lower Longvillian age. Elsewhere along the Alston Road fragments of the species have been collected at localities D, E, F and G, from the Lower Melmerby Beds.

In the main portion of the Inlier, specimens tentatively assigned to *B. ascripta* have been found at locality E. 3, Harthwaite Sike, near Dufton (see Text-fig. 4), in the upper part of the Corona Beds, belonging to the *Bancroftina typa* Zone of the Lower Longvillian. A fragmentary cranidium from this locality is figured (Pl. 16, fig. 14), and a large, distorted pygidium, BM. In. 54651, from the same horizon at locality E. 5 shows traces of eleven axial rings.

In their account of the Cross Fell Inlier Nicholson & Marr (1891 : 510) recorded " *Homalonotus rudis* Salter? " from the Corona Beds at Roman Fell, and the specimens were subsequently given the provisional name of *Brongniartella* cf. *rudis* (M'Coy) (Dean, 1959*a* : 209). More recently it has been pointed out that *Homalonotus rudis*, described originally by M'Coy (*in* Sedgwick & M'Coy, 1851 : 168) from North Wales, is not a recognizable species (Dean, 1961*a* : 355). Nicholson & Marr's specimens from Roman Fell, housed in the Sedgwick Museum and numbered A. 32906–12, are figured here for the first time (see Pl. 15, figs. 3, 6, 7, 9, 10). They

are too distorted tectonically for certain identification but are undoubtedly generally similar to *B. ascripta*. The pygidia show eleven or twelve axial rings, and one specimen has eight pairs of pleural ribs, though exaggerated by crushing. The best-preserved cranidium has proportions and a glabellar outline like *B. ascripta* but lacks the median carina, though this could well be due to tectonic causes In the absence of more definite specific features, it has been preferred to figure the Roman Fell specimens merely as *Brongniartella* sp. *B. ascripta* has not yet been recorded outside the Cross Fell Inlier.

Holotype. Sedg. Mus. A. 29632 (Pl. 15, fig. 11).

Brongniartella bisulcata (M'Coy)

(Pl. 16, fig. 8)

1851. *Homalonotus bisulcatus* M'Coy *in* Sedgwick & M'Coy, p. 168, pl. 1G, figs. 26, 27.
1961*a*. *Brongniartella bisulcata* (M'Coy) Dean, p. 346. This reference contains a full synonymy of the species.

Brongniartella bisulcata has been redescribed in detail from the type-area in south Shropshire (Dean, 1961*a*), and the material from the Cross Fell Inlier exhibits no features not already known. The earliest undoubted occurrence is in the upper half of the Upper Longvillian Substage at Swindale Beck, localities B. 5, 8 and 9. Fragmentary evidence suggests that it may also be found at the same horizon at Harthwaite Sike, locality E. 6. As in Shropshire, *B. bisulcata* is fairly common in the Marshbrookian Stage, at which level it is known from both Swindale Beck, localities B. 11, 14 and 16, and Harthwaite Sike, localities E. 7, 9, 10, 11 and 12. In the north of the Inlier, at the Alston Road outcrop, near Melmerby, fragments of *Brongniartella* occur in the lower part of the Upper Longvillian, but have not proved satisfactorily identifiable. They are undoubtedly close to *B. bisulcata* but may yet prove to belong to *B. ascripta*, a species originally described from adjacent and probably earlier strata.

Brongniartella depressa sp. nov.

(Pl. 16, figs. 1, 7, 10, 13)

1959*a*. *Brongniartella* sp. nov., Dean, p. 208.

Diagnosis. *Brongniartella* with glabella of low convexity, poorly defined both laterally and frontally, where outline narrows towards transversely-truncated, frontal, glabellar lobe. Occipital furrow almost absent from external mould. Axial furrows of thorax almost obsolete. Pygidial axis broad, poorly defined; axial rings and pleural ribs scarcely discernible.

Description. The cephalon is known only from a flattened cranidium, the median length of which is slightly less than half the maximum breadth. The glabella is slightly longer than wide, poorly defined laterally by markedly shallow axial furrows which are shallowest and straight frontally, but which then curve outwards and back from about their mid-points to the ends of the occipital ring. The dimensions of the holotype cranidium are as follows: max. length 16 mm.,

max. breadth 30 mm. (estimated) ; length of glabella 12·5 mm., max. breadth 11 mm., min. breadth 7·5 mm. The convexity of the glabella is remarkably low and the frontal glabellar lobe has a noticeably square appearance, being truncated by a poorly impressed, transversely straight, preglabellar furrow which meets the axial furrows almost at right-angles, the anterolateral angles of the frontal lobe being slightly rounded. The external mould of the holotype shows no trace of glabellar furrows but a presumably immature specimen (Pl. 16, fig. 13) carries three pairs of faintly-marked, almost equispaced, glabellar furrows on the internal mould, whereas the external mould of the same specimen shows no sign of lobation. The anterior border is slightly inclined forwards, transversely straight, uniformly broad (*sag.*), and is not well differentiated from the frontal glabellar lobe. The occipital furrow of the holotype is practically obsolete and the dorsal surface of the glabella is almost continuous with that of the occipital ring ; these two structures are uniformly broad (*tr.*) and the occipital ring is not obliquely truncated distally as, for example, is that of *Brongniartella bisulcata* (M'Coy). The internal mould of an immature cranidium, mentioned earlier, has a transversely straight, moderately-deep, occipital furrow (see Pl. 16, fig. 13) but the external mould of this specimen is almost smooth, comparable with the holotype. On both internal and external mould the pleuroccipital furrow is only moderately impressed, curving gently forwards laterally and delimiting a pleuroccipital segment of almost uniform breadth (*exsag.*). The genal angles are imperfectly known but appear to be rounded. Frontally the fixigenae are narrow, constricting forwards slightly and almost coalescing with the distal ends of the anterior border, from which they are separated by only shallow depressions representing the extension of the preglabellar furrow The posterior portions of the fixigenae are moderately declined, their breadth (*exsag.*) between one-quarter and one-third of the glabellar length. The palpebral lobes are small, short, situated opposite the mid-point of the glabella, and are moderately declined towards the axial furrows. The anterior branches of the facial suture are straight, converging forwards slightly so as to cut the anterior margin just outside the line of the axial furrows. The posterior branches are transversely straight at first but quickly turn backwards strongly to cut the genal angles in a normal gonatoparian position. The eyes, librigenae and hypostoma are not known.

Only one specimen of the thorax attributed to this species is known ; it is incomplete but there are traces of at least ten thoracic segments. The axis is only slightly convex, occupies approximately one-third of the total breadth, and is defined by almost obsolete axial furrows. The pleurae are transversely straight for the most part, but turn down and backwards distally, ending in bluntly-rounded tips. Each pleura carries a large anterolateral facet, delimited by a narrow, raised ridge running from the anterior margin, approximately mid-way between the axial furrow and the fulcrum, towards the posterolateral corner of the tip. Just outside the axial furrow, the frontal margin of each pleura is cut by a slit-like pleural furrow which runs outwards and slightly back so as to intersect the frontal margin mid-way between the fulcrum and the pleural tip.

One, almost complete pygidium ascribed to *B. depressa* is known, preserved as an external mould (Pl. 16, fig. 10). It is of depressed form, and broader than long in

the ratio 4 : 3 as far as measurements are possible. The frontal margin is moderately convex forwards and the posterior margin is broadly subparabolic in plan, with a rounded tip. The axis is broad, more than one-third the frontal breadth, defined laterally by faint axial furrows which are moderately convergent posteriorly. There are six or seven, almost indistinguishable, axial rings, followed by a short terminal piece which tends to merge into the posterior border, and there is no postaxial ridge. The pleural lobes are almost smooth, showing only traces of five pairs of pleural furrows, of which the first pair is the most clearly defined.

Internal moulds show a fine granulation probably resulting from the infilling of small canals within the test, but the exterior of the exoskeleton, though apparently smooth, proves, on magnification, to be markedly and finely punctate, the punctation extending even across the various furrows impressed on the dorsal surface.

Horizon and locality. A thin band of fossiliferous, weathered, impure limestone in the higher beds of the Dufton Shales, Pusgillian Stage, at Swindale Beck, locality B. 25.

Holotype. BM. In. 49882 (Pl. 16, fig. 1).

Paratypes. BM. In. 49881 (Pl. 16, fig. 7); In. 49884 (Pl. 16, fig. 10); In. 49885 (Pl. 16, fig. 13).

Discussion. The flattened form and lack of well-defined furrows on the external surface of the test readily distinguish *Brongniartella depressa* from any known species of the genus. Stratigraphically earlier species such as *B. ascripta* and *B. minor subcarinata* frequently exhibit a median carination of the glabella, the latter, together with the thoracic and pygidial axes, being well differentiated by axial furrows, whilst the pleural lobes of the pygidium are better segmented than is the case for *B. depressa*. The glabella of *B. bisulcata* undergoes a marked constriction at about its mid-point, and the anterolateral portions of the frontal glabellar lobe are less angular than those of *B. depressa*. The glabella of *Brongniartella platynota* (Dalman, 1828 : 135 ; Kielan, 1959 : 116, pl. 19, figs. 1–3), like that of the Pusgillian form, shows glabellar furrows only on the internal mould, and the occipital furrow is shallow externally, but the Swedish species has larger fixigenae, a better differentiated glabella which is markedly constricted frontally, and both the ring and pleural furrows of the pygidium are more strongly developed.

Brongniartella aff. ***platynota*** (Dalman)

(Pl. 16, fig. 5)

A single pygidium apparently distinct from coexisting forms in the Pusgillian Stage has been collected from the Dufton Shales in Swindale Beck, locality B 30. It is incomplete, preserved as an internal mould, and possesses at least seven axial rings and five pairs of pleural furrows. The axis is well defined by straight, moderately-deep, axial furrows which are convergent posteriorly, and the pleural lobes are moderately declined laterally. The anterior margin is convex forwards and the pleural ribs are directed backwards, but these features have almost certainly been exaggerated by crushing. Comparison with described species of *Brongniartella* is difficult, but the appearance is generally reminiscent of *B. platynota* (Dalman,

1828 : 135), a form originally described from the Ashgill Series of Sweden and since redescribed by Kielan (195 : 116, pl. 19, figs. 1–3). Each pygidium has a strongly convergent axis and well-defined pleural furrows, and as far as can be judged the number of axial rings and pleural ribs is generally similar.

Family Calymenidae Burmeister, 1843

The first serious attempt to subdivide the trilobites composing this family was made by Shirley who, in 1936, erected several new species and genera, and reviewed previous work on the group. Shirley's genera were later regarded by Richter (1937) as subgenera of *Calymene*, but most are now accepted as being of generic rank. The genus most abundantly represented in the Caradoc Series of the Anglo-Welsh area is that usually referred to as *Flexicalymene* Shirley, 1936, but recently Fisher (1957 : 13) has stated that *Orimops* Rafinesque, 1832, has precedence over the former, and it is necessary to investigate this claim further.

Several North American trilobite species were introduced by Green (1832) who, although he did not figure them, nevertheless gave valid diagnoses and provided sets of plaster casts of his original specimens. Among them was *Calymene callicephala* (Green, 1832 : 31), said to be from Hampshire, Virginia, a species which Rafinesque (1832 : 72), later in the same year, considered to be sufficiently distinct as to warrant the formation of a new subgenus of *Calymene* which he named *Orimops*, though he misspelt the specific name as *calicephala*. Many of Green's species are readily recognizable from their plaster casts, but that of *Calymene callicephala* is not one of the best, and the species is obviously in need of redescription. Consequently *Orimops* must be regarded as a *nomen dubium*, and may eventually prove to be best rejected. Nevertheless, the cast of *C. callicephala* shows enough of the structure of the cephalon to suggest that the species is similar in many respects to the well-known Cincinnatian trilobite *Calymene meeki* (Foerste, 1910 : 84, pl. 3, fig. 18 ; 1919, pl. 18, fig. 3), a form usually put in *Flexicalymene*, and in his original description of *C. callicephala* Green (1832 : 31) stated that his species occurred near Cincinnati, Ohio, though not at Trenton Falls. Both species are characterized by a markedly triangular glabellar outline, the sides of which are strongly convergent frontally to a narrow, frontal, glabellar lobe, and by the forward position of the eyes which, as in *Platycalymene*, are sited opposite the first pair of glabellar lobes. These two species, together with a closely similar form in the Ashgill Series of Scotland (Shirley, 1936, pl. 29, fig. 8), are regarded here as forming a compact group, both geographically and stratigraphically distinct. The name *Orimops*, if it is to be employed at all, is best used for these species, though the erection of a new name may prove necessary.

The genus *Flexicalymene* was founded by Shirley (1936 : 395) on the well-known south Shropshire trilobite *Calymene caractaci* Salter, 1865, one of several species in which the eyes are situated opposite the second glabellar lobes. Fisher's (1957, pl. 33, fig. 12) use of *Orimops* to include the Trenton trilobite *Calymene senaria* Conrad, 1841, even if the genus were not under suspicion, can hardly be justified and this species is regarded here as belonging to *Flexicalymene* (*s.s.*).

Shirley (1936 : 390–392) regarded the position of the eyes as being constant in most calymenids, and he supposed *Flexicalymene onniensis*, with the eyes situated far back, opposite the third glabellar furrows, to be exceptional. During the present work it has been noted that *F. onniensis* is only one of a number of widely distributed species, again falling within fairly well-defined geographical and stratigraphical limits, in which the eyes are similarly placed, and it is proposed now to separate these as a new genus to which the name *Onnicalymene* is given, with type species *Flexicalymene onniensis* Shirley.

Reacalymene was separated by Shirley (1936 : 395) as a distinct genus and a similar course has been followed by Whittard (1960 : 152, 158). In practice, however, whilst the ridging of the preglabellar field which Shirley claimed as a diagnostic feature is generally obvious, though never strongly developed, on the external mould, when only an internal mould is available all trace of the ridge frequently disappears and it is then impossible to distinguish the specimen from a typical *Flexicalymene*. For this reason it is thought better to follow the course adopted by Whittington (*in* Moore, 1959 : O.452) in regarding *Reacalymene* as being of subgeneric status within the genus *Flexicalymene*. As far as is now known, *Reacalymene* has a relatively restricted vertical range in the Anglo-Welsh area, perhaps through only the lower part of the Caradoc Series. Shirley (1936 : 390) postulated that the first stages in the thickening of the anterior border of the Calymenidae was to be found in *Reacalymene pusulosa* Shirley, from the early Caradoc strata of south Shropshire. This now appears to be an oversimplified view as *Gravicalymene*, with a much more thickened border, is known from the lowest Harnagian Stage, where it is represented by *G. praecox* (Bancroft), and may have existed even earlier.

The position of the calymenids normally placed in *Flexicalymene* may be summarized as follows :

Flexicalymene Shirley, 1936

Diagnosis. Glabellar outline generally subparabolic, rounded frontally. Anterior border moderately long, smooth, usually steeply inclined forwards. Palpebral lobes situated opposite, or almost so, second glabellar lobes. Thorax with thirteen segments (but see later).

Distribution. Llandeilo Series to Caradoc Series, probably to highest Marshbrookian Stage. Widely distributed geographically, occurring in England, Wales, Scotland, Ireland, Bohemia and eastern North America.

Typical species. *F. acantha* (Bancroft), *F. brevicapitata* (Porlock), *F. cambrensis* (Salter), *F. caractaci* (Salter), *F. declinata* (Barrande), *F. forcipata* (M'Coy), *F. planimarginata* (Reed), *F. senaria* (Conrad), *F. shirleyi* Tripp.

Onnicalymene gen. nov.

Diagnosis. Generally similar to *Flexicalymene*, but distinguished by anterior border, which is short and steeply inclined forwards, and by position of palpebral lobes, opposite third glabellar furrows and frontal portion of third glabellar lobes. Thorax with thirteen segments.

DISTRIBUTION. First encountered in the Actonian Stage of the Caradoc Series in the Anglo-Welsh area, *Onnicalymene* ranges upwards at least into the Pusgillian Stage. Its range in Ashgill strata is not known. Found in England, Wales, Sweden and southern Norway.

TYPICAL SPECIES. *O. jemtlandica* (Thorslund), *O. laticeps* (Bancroft), *O. onniensis* (Shirley), *O. salteri* (Bancroft).

Flexicalymene (Reacalymene) Shirley, 1936

DIAGNOSIS. Generally similar to *Flexicalymene* (*s.s.*) but anterior border bears low, transverse ridge, visible at least on external mould, and glabella is proportionately broader across third glabellar lobes, with sides more convergent forwards, producing triangular outline.

DISTRIBUTION Only confirmed from lower part of Caradoc Series in Welsh Borders, but possibly also in Llandeilo Series.

TYPICAL SPECIES. *F.* (*R.*) *limba* (Shirley), *F.* (*R.*) *pusulosa* (Shirley).

British Species of Doubtful Systematic Position

Calymene quadrata (King, 1923 : 504, pl. 26, figs. 1, 2), from the Ashgill Series, is generally referred to *Flexicalymene* but differs considerably from that genus in its glabellar outline, and is unique in having only twelve thoracic segments. Its position and affinities are therefore regarded as being doubtful.

Calymene (*Diacalymene*) *bigener* (Reed, 1935 : 47, pl. 1, fig. 3), from the Ashgill Series of Girvan, has been placed tentatively in *Reacalymene* by Shirley (1936 : 418), but such a position is doubtful and the species needs to be redescribed.

Calymene (*Ptychometopus*) *grayae* (Reed, 1935 : 45, pl. 1, figs. 13, 19?), from the Craighead Limestone, cannot be considered a recognizable species.

Calymene (*Colpocoryphe*?) *aldonensis* (Reed, 1935 : 48, pl. 1, figs. 14, 15), from the *Didymograptus superstes* Shales (= *Nemagraptus gracilis* Zone) of the Girvan district, has been placed in *Flexicalymene* by Shirley (1936 : 418), but the position of the eyes is reminiscent of that in *Onnicalymene*, whilst the glabellar outline is unlike that of any other described species of *Flexicalymene*.

Diacalymene and *Gravicalymene*

The typically Upper Ordovician or Silurian genus *Diacalymene* Kegel, 1927 has been reported from the Caradoc Series of south Shropshire, supposedly being represented by *D. praecox* Bancroft, 1949, but the species in question is considered here to be better placed in *Gravicalymene* Shirley, 1936. The two genera bear a considerable resemblance to one another in glabellar outline and it is sometimes difficult to differentiate between the respective anterior borders, which were described by Shirley (1936 : 395) as being " roll-like " in *Gravicalymene* and " ridged " in *Diacalymene*. The writer's observations suggest that whereas the type species of *Diacalymene*, *D. diademata* (Barrande), from the Silurian of Bohemia, possesses a distinctive, ridged, steeply-inclined anterior border, those Ordovician species

customarily assigned to the genus have an anterior border which is not markedly different from that of *Gravicalymene*, a genus which did not undergo much modification even as late as the Devonian. A more important criterion for separating the two genera is the presence or absence of what Shirley called " papillate second glabellar lobes ", accompanied by " buttresses " on the fixigenae opposite the same lobes. Stumm & Kaufmann (1958 : 949) have drawn attention to the unsuitability of this terminology, and it is suggested that one might more appropriately speak of " conjugate second glabellar lobes and genal buttresses " in *Diacalymene*. Hupé (1955 : 245) has attempted to place *Diacalymene* and *Gravicalymene* in separate subfamilies, respectively Calymeninae and Colpocoryphinae, on the basis of their having unconstricted or constricted axial furrows, but such a course seems obviously unworkable. *Diacalymene diademata* differs in some respects from the described Ordovician species of the genus, the latter in turn resembling *Gravicalymene* in glabellar outline. It seems likely that the two genera are closely related, and may have diverged from a common ancestral group earlier in the Ordovician, but more evidence is needed. As restricted in this paper, *Diacalymene* makes its appearance in the Anglo-Welsh area in the Pusgillian Stage of the Cross Fell Inlier, being unknown in Shropshire ; it becomes more abundant in the succeeding Ashgill Series and continues into the lower Silurian. *Gravicalymene*, though ranging as high as the Devonian, is an earlier genus, known with certainty from the Harnagian Stage of the type Caradoc succession but possibly originating still earlier. In Caradoc strata both genera are subordinate in numbers to the widespread *Flexicalymene* and *Onnicalymene*.

Genus ***FLEXICALYMENE*** Shirley, 1936

Type Species. *Calymene Blumenbachii* var. *Caractaci* Salter, 1865 by original designation of Shirley (1936 : 395).

Flexicalymene cf. ***caractaci*** (Salter)

(Pl. 13, fig. 10)

1959*a*. *Flexicalymene* cf. *caractaci* (Salter) : Dean, p. 214.

Calymenid remains have been found at several points in the vicinity of the Alston Road near Melmerby, and some of the better preserved are generally comparable with Salter's species. The type-material of *F. caractaci* came from the Upper Cheney Longville Flags, Marshbrookian Stage, of south Shropshire and has been redescribed by Shirley (1931 : 25). In the Cross Fell Inlier only occasional fragments of calymenid trilobites have been collected from the Marshbrookian Stage, and none has proved identifiable. The strata at Melmerby are probably both Lower and Upper Longvillian in age, and the relevant localities there comprise C to J inclusive, and possibly also locality A (see Text-fig. 5). The lectotype of *Flexicalymene planimarginata* (Reed), redescribed by Shirley (1931 : 22) and Harper (1947 : 167), originated from the Lower Longvillian of North Wales. The species has not yet been reported from the Cross Fell Inlier at this horizon, though

Whittard (1960 : 158) has recorded it earlier, from the Soudleyan Stage of the Shelve Inlier.

Genus *ONNICALYMENE* nov.

TYPE SPECIES. *Flexicalymene onniensis* Shirley, 1936. For diagnosis of genus see p. 112.

Onnicalymene onniensis (Shirley)

(Pl. 13, fig. 7 ; Pl. 14, figs. 1, 2, 7, 10)

1936. *Flexicalymene onniensis* Shirley, p. 405, pl. 29, figs. 5–7.
1949. *Flexicalymene onniensis* Shirley : Bancroft, p. 308, pl. 11, figs. 36, 37.
1958. *Flexicalymene onniensis* Shirley : Dean, p. 224.
1959*a*. *Flexicalymene onniensis* Shirley : Dean, pp. 200, 207.
1959*a*. *Flexicalymene* aff. *onniensis* Shirley : Dean, pp. 202, 208.

This well-known Shropshire species occurs in abundance in the Dufton Shales of the Knock-Dufton district of the Cross Fell Inlier. The earliest specimens are from the *Onnia gracilis* Zone at Pus Gill, localities A. 8, 9, 11, 12, 14 and 15, and the species has been found less commonly in the *Onnia superba* Zone, also at Pus Gill, locality A. 5. Specimens are relatively abundant in rocks of the Pusgillian Stage, and do not appear to be restricted to any particular part of the stage. Localities are numerous and include : Pus Gill, localities A. 1, 6, 18, 21, 24, 25–30 ; Swindale Beck, localities B. 22, 24–26, 28, 33, 34 ; Dufton Town Sike, localities C. 2–4 ; and Hurning Lane. Judging from the matrix of the Pus Gill specimen figured by Shirley (1936, pl. 29, fig. 7) it probably originated from the Pusgillian Stage.

Onnicalymene laticeps (Bancroft)

(Pl. 14, figs. 5, 6)

1949. *Flexicalymene laticeps* Bancroft, p. 307, pl. 11, figs. 33, 33*a*.
1959*a*. *Flexicalymene* cf. *laticeps* Bancroft : Dean, pp. 199, 207.

Fragments referable to this characteristic south Shropshire form have been recovered from locality B. 15 in the bed of Swindale Beck, near the eastern bank, and the best preserved, a cephalon with three attached thoracic segments, is figured here. In Shropshire *O. laticeps* has been found only in the Actonian Stage, particularly the middle third, and the associated fauna at Swindale Beck, comprising *Chasmops* cf. *extensa* (Boeck), *Remopleurides* sp. (see p. 127), *Chonetoidea*, *Onniella* and *Sowerbyella*, suggests a similar horizon. Like other members of *Onnicalymene*, *O. laticeps* has the palpebral lobes sited well back, opposite the third glabellar furrows, but is easily separated specifically by the short glabella with its well-rounded, parabolic outline. Bancroft's original account of the species did not describe the pygidium. Two pygidia, numbered BM. In. 50259 and In. 50260, have been found in association with the figured cephalon at Swindale Beck, and are of characteristic calymenid form. The axis has five well-defined axial rings, with

faint traces of a sixth, followed by a short terminal piece. Each pleural lobe carries five pleural ribs with faintly impressed rib furrows which deepen distally ; the ribs are separated from each other by deep pleural furrows running from the axial furrows to the lateral margins.

Genus ***DIACALYMENE*** Kegel, 1927

TYPE SPECIES. *Calymene diademata* Barrande, 1852 by original designation of Kegel (1927 : 617).

Diacalymene cf. ***marginata*** Shirley

(Pl. 13, fig. 13 ; Pl. 14, fig. 11)

1936. *Diacalymene marginata* Shirley, p. 415, pl. 29, figs. 19, 20.
1959*a*. *Diacalymene* cf. *marginata* Shirley : Dean, pp. 204, 208.

Diacalymene marginata was described from the Drummuck Group, Ashgill Series, of the Girvan district by Shirley, who also recorded the species from the Ashgill of North Wales and the Cautley district of Yorkshire. The specimens from the Cross Fell Inlier are closely similar to the holotype in most respects, though the glabella may be slightly broader frontally and the anterior border situated a little closer to the frontal glabellar lobe. Such differences may well be due to tectonic causes. This form is known from the topmost beds of the Pusgillian Stage at locality B. 25, and perhaps also B. 34, in Swindale Beck. At both places the horizon is not far below the disconformable base of the Swindale Limestone. Elsewhere in the Inlier *D.* cf. *marginata* has been found at locality A. 27 in Pus Gill ; the horizon here is also in the Pusgillian Stage, but is probably lower than those at Swindale Beck, though the relationships of the strata are obscured by strike-faulting.

Genus ***GRAVICALYMENE*** Shirley, 1936

TYPE SPECIES. *Gravicalymene convolva* by original designation of Shirley (1936 : 395).

Gravicalymene jugifera sp. nov.

(Pl. 13, figs. 9, 11 ; Pl. 14, figs. 3, 4, 8, 9)

1959*a*. *Gravicalymene* sp. nov., Dean, pp. 204, 208.

DIAGNOSIS. *Gravicalymene* with well-rounded frontal glabellar lobe, and glabella which is relatively narrow for genus. Anterior border of cephalon flattened dorsally, its posterior margin ridged, separated by deep, broad (*sag.*) furrow from glabella. Pygidium of characteristic calymenid shape with five axial rings and five pleural ribs.

DESCRIPTION. The cranidium is moderately convex, both longitudinally and transversely, and about twice as broad as long. The glabella is a little broader than long, its sides gently convergent forwards for the most part, but the breadth increases noticeably at the line of the basal glabellar lobes. The frontal glabellar

lobe is short, its anterior margin well rounded. There are three pairs of lateral glabellar lobes, those of the first pair being small, tubercle-like, bounded frontally by shallow, slit-like, first glabellar furrows and posteriorly by wider (*exsag.*), deeper, second glabellar furrows. The second glabellar lobes are larger than those of the first pair, and subcircular in plan. The third glabellar furrows are deep, at first directed slightly backwards from the axial furrows but then bifurcating markedly, the anterior branch so formed being the shorter, curving adaxially forwards around the second glabellar lobes. The posterior branches are deeper and turn backwards towards, though they do not attain, the occipital furrow. The third, or basal glabellar lobes are subangular in plan with gently convex distal margins, bluntly pointed frontally, and are constricted proximally by the posterior branches of the third glabellar furrows. The axial furrows are deep, gently sigmoidal in plan, and of generally uniform breadth except posteriorly, where they narrow slightly as they flex around the basal glabellar lobes. There are deep hypostomal pits situated midway between the first glabellar furrows and the line of the front of the glabella. There is no true preglabellar field or furrow present, and the portion of the cranidium immediately in front of the glabella is continuous with the anterior border, the whole being flexed upwards through about a right-angle. The structure so formed carries a ridge, moderately defined medially but dying out laterally, which marks the junction of the smooth, broad (*sag.*), deep furrow immediately in front of the glabella, and the granulate, flattened, moderately-inclined top of the anterior border. The occipital ring is transversely convex, broadest (*sag.*) medially, becoming narrower laterally towards a pair of poorly-defined occipital lobes. The occipital furrow is shallow and transversely straight medially, deepening laterally where it curves backwards slightly to encompass the basal glabellar lobes. The pleuroccipital furrow is broad (*exsag.*), of moderate depth, becoming shallower abaxially; the pleuroccipital segment is narrow proximally, broadening towards the rounded genal angles. The anterior parts of the fixigenae are of uniform breadth, converging forwards slightly, parallel to the axial furrows. The eyes are situated opposite the second glabellar furrows and the front half of the second glabellar lobes. The visual surface has not been found preserved, and the palpebral lobes are moderately declined adaxially, with only traces of palpebral furrows. Poorly-developed eye ridges run obliquely forwards from the palpebral lobes, ending at the axial furrows opposite the first glabellar lobes. The librigenae are of characteristic calymenid type, steeply declined laterally. The hypostoma is unknown.

The thorax is represented by only one crushed example in which the number of thoracic segments is not visible. In spite of the poor state of preservation the segments do not appear to differ significantly from those of other calymenids.

In plan the pygidium is broadly kite-shaped, the anterior margin strongly curved forwards and the lateral margins straight, converging backwards to a blunt point. The axis is convex dorsally, defined laterally by deep axial furrows extending almost to the tip. Excluding the articulating half-ring there are four well-developed axial rings, separated by deep, transversely-straight ring furrows, with a fifth less obvious axial ring, followed by a relatively long terminal piece extending almost to the tip of the pygidium, to which it is linked by a suggestion of a low postaxial ridge. The

pleural lobes carry four pairs of well-developed pleural ribs which become progressively less divergent backwards, with traces of a fifth pair almost parallel to one another. The ribs of the first pair have interpleural furrows only on the distal half of the dorsal surface, but on the remaining pairs the interpleural furrows extend from just outside the axial furrows to the lateral margins, dividing each rib into two bands, of which the anterior is the narrower (*exsag.*).

Excluding the furrows, which are apparently smooth, the surface of internal moulds is generally finely granulate, representing the infilling of canals within the original test. A little of the test remains on the holotype cranidium, and the inclined, upper surface of the anterior border is finely granulate whilst that of the broad (*sag.*) furrow immediately in front of the glabella is smooth.

Horizon and localities. All the known occurrences of *Gravicalymene jugifera* are in Dufton Shales belonging to the Pusgillian Stage. The holotype is from Swindale Beck, locality B. 28, but the species is known also from Pus Gill, locality A. 24 ; Swindale Beck, localities B. 20, B. 30 and, with some doubt, B. 25 ; Dufton Town Sike, locality C. 6 ; Billy's Beck, locality D. 1 ; and at Hurning Lane, 700 yards north-east of St. Cuthbert's Church, Dufton.

Holotype. BM. In. 50263 (Pl. 14, figs. 3, 4, 8).

Paratypes. BM. In. 50245 (Pl. 13, figs. 9, 11) ; In. 55897.

Discussion. *Gravicalymene jugifera* seems to be closely related to the type-species of the genus, *G. convolva*, which was described from the Ashgill Series of Birdshill Quarry, near Llandilo (Shirley, 1936 : 409, pl. 29, figs. 16–18). The new species may, however, be distinguished by its slightly narrower glabellar outline, smaller basal glabellar lobes, more dorsally flattened anterior border, and by the greater breadth (*sag.*) of the furrow separating the anterior border from the frontal glabellar lobe. Both species have a glabellar outline remarkably close to that found in certain Ordovician species of *Flexicalymene* (*s. l.*) described by Stumm & Kaufmann (1958 : 951, 953, pl. 123, figs. 14, 15 ; pl. 124, figs. 2–16) from Michigan, but are distinguished by the different structure of the anterior border.

Family Dimeropygidae Hupé, 1953

Genus ***TOERNQUISTIA*** Reed, 1896

Type species. *Cyphaspis* (*Törnquistia*) *nicholsoni* (Reed, 1896 : 433) by monotypy.

Toernquistia aff. ***reedi*** Thorslund

(Pl. 16, figs. 2, 3)

1910. *Törnquistia nicholsoni* (Reed) Reed, p. 211.
1940. *Törnquistia reedi* Thorslund, p. 148, pl. 10, figs. 14–19 ; pl. 11, fig. 15.

Only a small, incomplete cranidium preserved as an internal mould is available. The calculated length is estimated to have been about 2 mm. and the breadth across the palpebral lobes 2·3 mm. The glabella is subparabolic in outline, moderately convex, bounded laterally by deep, narrow, axial furrows which are continuous

frontally with the preglabellar furrow. There are no glabellar furrows. The fixigenae are narrow, lower than the glabella and continuous frontally with the preglabellar field. The latter is broad (*exsag.*) distally, but narrows towards the median line where a deep pit is situated in the preglabellar furrow; from this pit a slot-like depression extends forwards almost half-way across the steeply-declined, preglabellar field. The anterior border is narrow (*exsag.*), almost flat, separated from the preglabellar field by a narrow (*exsag.*), shallow, anterior border furrow. The surviving left palpebral lobe, though incomplete posteriorly, is long and narrow, separated from the fixigena by a broad, shallow, palpebral furrow. In front of the palpebral lobes the anterior branches of the facial suture diverge strongly towards the margin. All the furrows of the cranidium are smooth, but the surface of the anterior border is finely granulate, whilst that of the glabella, palpebral lobes and preglabellar field is covered with small tubercles which increase in size on the distal portions of the fixigenae.

Horizon and locality. Probably that denoted here by the letter J (see Text-fig. 5), east of the Alston Road, north-east of Melmerby. The rocks probably belong to the Lower Melmerby Beds, Lower Longvillian Substage.

Discussion. In emending the Family Dimeropygidae, Whittington & Evitt (1954 : 35) placed therein the genera *Dimeropyge* Öpik, *Dimeropygiella* Ross, *Toernquistia* Reed, *Mesotaphraspis* Whittington & Evitt, and *Chomatopyge* Whittington & Evitt. They noted the species described by Thorslund (1940 : 148) as *Törnquistia reedi*, but considered its generic position to be uncertain owing to its possessing a cephalon recalling that of *Mesotaphraspis* and a pygidium resembling that of *Chomatopyge*. Until more material is available the systematic position of the Alston Road form is debatable. Generically it appears to be closer to *Toernquistia* than to *Mesotaphraspis*, whilst bearing a considerable resemblance to Thorslund's species, though the latter has faint glabellar furrows and a striate anterior border. The type material of *Toernquistia reedi* was obtained from the limestone facies of the Lower Chasmops Limestone, 4bβ, of Jemtland, Sweden, a horizon which may not differ appreciably from that of the Alston Road species.

Toernquistia nicholsoni Reed sp. (1896 : 433, pl. 21, figs. 3, 3*a*; see also Whittington, 1950 : 561, pl. 75, figs. 8–16), from the Keisley Limestone of Ashill age in the Cross Fell Inlier, differs in having palpebral lobes situated farther forwards, and in being proportionately narrower across the frontal glabellar lobe.

The trilobite originally described by Reed (1904 : 86, pl. 12, figs. 3–7) as *Menocephalus*? (*Törnquistia*) cf. *nicholsoni*, from the Balclatchie Group of Girvan bears a strong resemblance to that from the Alston Road, but differs from the latter in having a more transversely straight, anterior cephalic border, as well as a pair of deep furrows running distally from the mid-points of the axial furrows to just in front of the palpebral lobes. The Balclatchie species was later renamed *Hystricurus translatus* by Reed (1931 : 6), and placed in *Toernquistia* by Whittington (1950 : 563). Hupé (1955 : 143, fig. 124, 6*a*, *b*) has since recorded " *Törnquistia nicholsoni* Reed " from the Llandeilo Series of Scotland, and it must be presumed that his paper refers to *Toernquistia translata*, as no genuine record of *T. nicholsoni* is known from pre-Ashgill strata.

Family Illaenidae Hawle & Corda, 1847

Genus ***STENOPAREIA*** Holm, 1886

Type species. *Illaenus linnarssoni* Holm, 1882 by original designation of Holm (1886 : 152).

Stenopareia? sp.

(Pl. 16, fig. 12)

1910. *Illaenus Bowmani* [*sic*] Salter (?), Reed, p. 211.

A single pygidium recorded by Reed (1910 : 211) is the only-known representative of the family in the Caradoc Series of the Inlier. The specimen is relatively long, the median length only slightly less than the maximum breadth. *Stenopareia* has been accepted as a distinct genus by Jaanusson (1954 : 570–572), and he has been followed by Whittard (1961*a* : 216, pl. 30, figs, 10–13) who has described a new species, *S. camladica*, from the Lower Soudleyan Stage of west Shropshire. The pygidium of *S. camladica* bears a considerable resemblance to that from the Inlier, but detailed comparison is not possible owing to lack of material.

Horizon and locality. Probably the Lower Melmerby Beds at locality J near the Alston Road (see Text-fig. 5).

Family Lichidae Hawle & Corda, 1847

Subfamily Homolichinae Phleger, 1936

Genus ***CONOLICHAS*** Dames, 1877

Type species. *Lichas aequiloba* Steinhardt, 1874 by subsequent designation of Vogdes (1890 : 23).

Conolichas melmerbiensis (Reed)

(Pl. 17, figs. 14, 16 ; Pl. 18, figs. 1–4)

1907. *Lichas* (*Homolichas*) *melmerbiensis* Reed, p. 396, pl. 17, figs. 1–7.
1910. *Lichas melmerbiensis* Reed : Reed, p. 211.
1933. *Platylichas melmerbyensis* (Reed) Bancroft, table 2.
1937. *Tetralichas melmerbiensis* (Reed) Phleger, p. 1088.
1939. *Conolichas melmerbiensis* (Reed) Warburg, p. 73.
1946. *Platylichas melmerbiensis* (Reed) : Bancroft *in* Lamont, p. 237.
1948. *Platylichas melmerbiensis* (Reed) : Bancroft *in* Lamont, p. 416.
1958. *Conolichas melmerbiensis* (Reed) : Tripp, p. 576.
1959*a*. *Conolichas melmerbiensis* (Reed) : Dean, pp. 213, 214.

All Reed's type-specimens were described by him merely as having been collected from what he called the Dufton Shales near Melmerby. The manuscript catalogue accompanying the specimens, together with their state of preservation, suggests that the place of origin was locality J, east of the Alston Road, near Melmerby (see Text-fig. 5), and during the present field-work two more specimens of the species

have been obtained from this locality. The horizon is in the Longvillian Stage, and the rocks at locality J are believed to belong to the Lower Melmerby Beds, of probable Lower Longvillian age. It was claimed by Bancroft (1933, table 2 ; *in* Lamont, 1948 : 416) that what he called *Platylichas melmerbiensis* occurred near Melmerby with *Wattsella horderleyensis* Whittington, but the latter, a zonal brachiopod species in the Lower Longvillian of south Shropshire and North Wales, has not yet been confirmed in the Cross Fell Inlier. The type-specimens of *Conolichas melmerbiensis* are unusual in including several whole, or nearly whole, exoskeletons, and it may be that they occurred at only one restricted horizon where conditions were particularly suitable for their preservation.

LECTOTYPE, here selected. Sedg. Mus. A. 29638 (Pl. 18, figs. 3, 4).

PARATYPES. Sedg. Mus. A. 29637 (Pl. 18, fig. 1) ; A. 29639 ; A. 29640 ; A. 29641 (Pl. 17, fig. 16) ; A. 29642 (Pl. 18, fig. 2) ; A. 29643 (Pl. 17, fig. 14).

Genus ***PLATYLICHAS*** Gürich, 1901

TYPE SPECIES. *Lichas margaritifer* Nieszkowski, 1857 by original designation of Gürich (1901 : 522).

Platylichas cf. ***laxatus*** (M'Coy)

(Pl. 17, figs. 1, 7)

1959*a*. *Platylichas laxatus* (M'Coy) (s.l.) : Dean, pp. 204, 207, 208.

Lichas laxata was described by M'Coy (1846 : 51, pl. 4, fig. 9) from southern Ireland, and founded by him on an incomplete, compressed cranidium, now in the National Museum of Ireland, from Ballygarvan Bridge, New Ross. The species has since been widely quoted by a number of authors from a variety of horizons within the Caradoc and Ashgill Series, and although it seems likely that more than one species may be present, comparison with other forms will continue to be difficult until a detailed redescription is available on the basis of topotype material. A long description was given by Warburg (1939 : 118) using Scandinavian material of Caradoc and Ashgill age. The cranidia of these specimens appear indistinguishable from each other, and the pygidia exhibit only occasional minor differences which may or may not be of specific significance. The specimens from the Chasmops Limestone of Norway and Sweden cannot reasonably be separated from those now under consideration from the Cross Fell Inlier, particularly when allowance is made for variation within the species.

In the Anglo-Welsh Caradoc Series, *Platylichas* of the *laxatus* type has been found as early as the Derfel Limestone (Whittington & Williams, 1955 : 424, pl. 40, figs. 113–118), whilst the Longvillian strata of North Wales contain remains identical with *Lichas nodulosus* (M'Coy *in* Sedgwick & M'Coy, 1851 : 151, pl. 1F, fig. 16). Tripp (1958 : 579, pl. 85, fig. 5) has refigured the holotype of the latter species and considers it to be synonymous with *Platylichas laxatus*, though pointing out that it may eventually prove to merit subspecific status. The specimen is

incomplete but exhibits, nevertheless, a remarkably close resemblance to a pygidium figured here (Pl. 17, fig. 7).

The earliest-known occurrence of *Platylichas* in the Cross Fell Inlier is in the Upper Melmerby Beds of the Alston Road outcrop, locality H (see Text-fig. 5). The sole specimen found (Pl. 17, fig. 2) is a fragmentary pygidium, numbered BM. In. 52595, which belongs unmistakably to the genus but which is insufficient for specific comparison and is accordingly named merely *Platylichas* sp.

The two figured specimens of *Platylichas* cf. *laxatus* (M'Coy) are from the highest beds of the Dufton Shales, Pusgillian Stage at Swindale Beck, locality B. 25. They are numbered BM. In. 50115 (Pl. 17, fig. 1) and In. 50117 (Pl. 17, fig. 7). What is apparently the same form is known earlier, in Dufton Shales of the Onnian Stage, *Onnia gracilis* Zone, at Pus Gill, localities A. 12, 13 and 14.

Family Odontopleuridae Burmeister, 1843

Genus ***PRIMASPIS*** R. & E. Richter, 1917

Type species. *Acidaspis primordialis* Barrande, 1852 by original designation of R. & E. Richter (1917 : 466).

Primaspis semievoluta (Reed)

(Pl. 17, figs, 3, 10, 11, 13, 15)

1910. *Acidaspis semievoluta* Reed, p. 214, pl. 17, figs. 1–3.
1959*a*. *Primaspis semievoluta* (Reed) Dean, p. 214.

All Reed's syntypes are believed to have been obtained from the Lower Melmerby Beds, probably Lower Longvillian Substage, at locality J near the Alston Road (see Text-fig. 5). During the present work one further specimen has been collected from what is believed to be the same geological horizon at locality F beside the Alston Road ; this specimen, a distorted cranidium, is in the British Museum, where it is numbered In. 53000.

Few species of Odontopleuridae are known from the Anglo-Welsh Caradoc Series. *Primaspis harnagensis* (Bancroft, 1949 : 301, pl. 10, figs. 21, 22), from the Harnagian Stage of Shropshire, has a narrower glabellar outline than *P. semievoluta*, and the pygidium has seven pairs of marginal spines, compared with five pairs on the Cross Fell species. One of the paratypes of *P. semievoluta* (see Pl. 17, fig. 10) has a relatively narrow glabella not unlike that of *P. harnagensis*, but this is believed to be the result of tectonic distortion. The lectotype cranidium of *Primaspis semievoluta* bears a noticeable resemblance to that of *Primaspis caractaci* (Salter, 1857 : 211, pl. 6, figs. 15–17), a species found most commonly in the Actonian Stage of south Shropshire. The glabella of the Shropshire form is, however, slightly broader across the basal glabellar lobes, and a little more pointed frontally. The pygidia are more distinct, that of *P. semievoluta* having five pairs of marginal spines, compared with six pairs in *P. caractaci*. In each case the third pair of spines is longer and stouter than the others.

Lectotype, here selected. Sedg. Mus. A. 29951 (Pl. 17, fig. 3).

Paratypes. Sedg. Mus. A. 29952 (Pl. 17, fig. 10); A. 29953 (Pl. 17, fig. 15); A. 29954 (Pl. 17, fig. 11).

Odontopleurid gen. et sp. ind.

Apart from the occurrence of *Primaspis semievoluta* (Reed) in the Alston Road outcrop, the only other evidence of the family in the Caradoc Series of the Inlier is an unidentifiable fragment from the Dufton Shales, Pusgillian Stage, at Dufton Town Sike, locality C. 6 (see Text-fig. 4), collected by Mr. M. Mitchell. The specimen, BM. In. 51848, is an external mould showing part of the glabella with two pairs of glabellar lobes, the right palpebral lobe, situated opposite the basal glabellar lobe, and a wide (*sag.*) occipital ring carrying a small but well-defined median tubercle. There are traces of three thoracic segments and the surface of the test is ornamented with large closely-set granules. The general aspect is not unlike that of a species of *Primaspis* but the specimen is inadequate for even generic determination.

In describing *Acidaspis magnospina* from the Ashgill Series of the southern Lake District, Stubblefield (1928 : 427) stated that his new species was probably the same as that recorded by Marr (1892 : 108) as "*Acidaspis* n. sp." from the "Sleddale Group of Pusgill and Applethaite". Earlier, Nicholson & Marr (1891 : 511), in listing the fossils then known from the Dufton Shales, noted "*Acidaspis* n. sp." from "Pusgill" and the specimen is in the Sedgwick Museum, where it is numbered A. 32956. The species is apparently *Acidaspis magnospina* Stubblefield, but the matrix is not that of the Dufton Shales; it resembles instead the lithology of the so-called *Staurocephalus* or Swindale Limestone, a horizon not known from Pus Gill but which crops out at Swindale Beck and Billy's Beck, and the specimen is probably mislabelled.

Family Otarionidae R. & E. Richter, 1926

Genus ***OTARION*** Zenker, 1833

Type species. *Otarion diffractum* Zenker, 1833 by subsequent designation of R. & E. Richter (1926 : 95).

Otarion sp.

(Pl. 17, figs. 4, 12)

? 1891. *Cyphaspis megalops* M'Coy (?) : Nicholson & Marr, p. 509.
1959*a* *Otarion* sp., Dean, p. 214.

Two indifferently-preserved cranidia from the Upper Melmerby Beds, Upper Longvillian Substage, at locality H by the Alston Road, represent the only specimens of the genus known from the Cross Fell Inlier. The more complete example, figured here, bears a general resemblance to the cephalon of *Otarion planifrons* (Eichwald), a Baltic species from the Kuckers Stage which has been refigured by Öpik (1937, pl. 2, figs. 1, 2, text-fig. 2). The proportions of the glabella, and the size and position

of the basal glabellar lobes, is similar in both species, but the glabella of *O. planifrons* is the more coarsely tuberculate and possesses a preglabellar field which is slightly longer. *Otarion isoplates* Tripp (1954 : 669, pl. 3, figs. 1–4) has a preglabellar field and anterior border very like those of the Alston Road form but the basal glabellar lobes are slightly larger and project farther abaxially.

Family Proetidae Salter, 1864

Subfamily Proetidellinae Hupé, 1953

Kielan (1959 : 69) has declared that the Subfamily Proetidellinae is synonymous with that of the Proetinae, on the grounds that Hupé's subdivision is unsatisfactorily diagnosed, utilizing only the degree of divergence of the anterior branches of the facial suture. The type genera of these two subfamilies differ considerably in several respects, including the presence in *Proetidella* of a definite preglabellar field such as is not seen in *Proetus*. Accordingly the writer prefers to follow Richter & Struve (*in* Moore, 1959 : O.395) in retaining Proetidellinae as a distinct Subfamily.

Genus ***PROETIDELLA*** Bancroft, 1949

Type species. *Proetidella fearnsidesi* by original designation of Bancroft (1949 : 304).

Proetidella? marri sp. nov.

(Pl. 16, figs. 4, 6, 9 ; Pl. 17, figs. 5, 6, 8, 9)

1959*a*. *Proetidella* aff. *fearnsidesi* Bancroft : Dean, p. 206.

Diagnosis. Glabella of approximately equal length and breadth, broadest posteriorly, narrowing frontally to gently rounded frontal lobe. Preglabellar field long, flat ; anterior border brim-like in form, steeply inclined. Palpebral lobes narrow, extending backwards almost to occipital furrow.

Description. The cephalon is known only from discrete cranidia and librigenae. The glabella is roughly as broad as long, gently convex longitudinally and transversely, its line of greatest breadth situated a little way in front of the occipital furrow. The glabellar outline constricts frontally, and glabellar furrows are totally absent. The axial furrows are only moderately deep, converging frontally around the anterolateral angles of the frontal lobe, the anterior margin of which is gently convex, to become continuous with the preglabellar furrow, which is of similar depth. The preglabellar field is flat, fairly long (*sag*), equal to about one-quarter of the length of the glabella, arched forwards gently, and differentiated by only a poorly-defined furrow from the anterior border. The last-named structure forms a conspicuous, raised brim to the front of the cranidium and is generally steeply inclined forwards, though the angle may vary according to the state of preservation. The occipital ring is slightly convex transversely, less so longitudinally, of greatest length (*sag.*) medially but shortening a little laterally where it forms a pair of ill-

defined occipital lobes. The hindmost parts of the fixigenae have not been found preserved; frontally they form only a thin, rim-like continuation of the preglabellar field, and medially are not differentiated from the palpebral lobes. The latter are narrow, declined proximally, and extend from opposite the mid-point of the glabella almost to the line of the occipital furrow. The librigenae are known only from dissociated specimens, and the ocular surface of the eye has not been found preserved. Beneath each eye is a poorly-defined eye-platform from which the convex upper surface of the librigena declines steeply to a deep, broad, lateral border furrow; beyond the latter is a well-developed lateral border which passes backwards into a librigenal spine of moderate length. The pleuroccipital furrow is well defined and of moderate depth, intersected by the lateral border furrow without reaching the margin; the pleuroccipital segment becomes broader (*exsag.*) laterally, where it passes without interruption into the librigenal spine. As far as can be judged from both cranidia and librigenae, the posterior branches of the facial suture run laterally back from the posterior end of the eyes to cut the cephalic margin only a short distance outside the axial furrows; the anterior branches converge from the eyes almost to the axial furrows but then curve anterolaterally to cut the anterior border longitudinally in-line with the palpebral lobes

The hypostoma and thorax are not known.

One almost complete pygidium attributed to the species has been collected. The frontal breadth is between two and three times the median length, and the outline is generally semi-elliptical, though the frontal margin is gently curved back laterally. The axis is well defined, the sides converging backwards only gently, and does not quite reach the tip of the pygidium. It is strongly convex transversely and stands well above the pleural lobes, which are only a little declined to the entire lateral margins. It is estimated that there are five axial rings, with a short terminal piece. The most complete specimen has four pairs of pleural furrows, the first pair slightly more impressed than the rest (Pl. 17, fig. 6), and an additional specimen, In. 55880, shows that each of the pleural ribs is divided by a shallow interpleural furrow into two unequal bands, of which the anterior is the narrower (*exsag.*). As far as can be ascertained, both sets of furrows extend to the lateral margin.

The dorsal surface of the glabella, occipital ring and anterior border is covered with thin, slightly-raised, anastomosing ridges arranged in a Bertillon pattern, but the furrows of the cranidium, together with the preglabellar field, are smooth. The librigenae have not been found sufficiently well preserved to ascertain whether they are so ornamented, but the doublure can be seen to be covered with terrace lines subparallel to the lateral margin. The test of the pygidium is not adequately known.

Horizon and locality. Corona Beds belonging to the Lower Longvillian Substage, *Bancroftina typa* Zone, at Harthwaite Sike, locality E. 3, east of Dufton (see Text-fig. 4).

Holotype. BM. In. 54644 (Pl. 16, fig. 4; Pl. 17, fig. 8).

Paratypes. BM. In. 54645 (Pl. 17, fig. 5); In. 54646 (Pl. 16, fig. 9); In. 54647 (Pl. 16, fig. 6); In. 54648 (Pl. 17, fig. 9); In. 55880; In. 55881; In. 55882 (Pl. 17, fig. 6).

Discussion. The holotype of *Proetidella fearnsidesi* has recently been refigured in the form of a line drawing by Struve (*in* Moore, 1959 : O. 396, fig. 301, 1) but his illustration is somewhat misleading. The original specimen is preserved as a flattened external mould in shaly mudstone, and the glabella is distorted by crushing. The species is to be redescribed by the writer in a future paper, but in the meantime it may be stated that the presence in Struve's illustration of a bluntly-pointed frontal glabellar lobe, together with a pair of basal glabellar lobes, is the result of crushing. In addition, the pygidium of the holotype has well-defined pleural furrows extending to the lateral margins, as well as traces of interpleural furrows.

In *Proetidella*? *marri* the attributed pygidium is shorter than that of the Shropshire species, with fewer pleural furrows and axial rings, numbering four and five respectively compared with five and seven. The narrowing of the frontal glabellar lobe of the Cross Fell form, together with its more transverse frontal margin, are features not seen in *P. fearnsidesi*. The frontal portion of the cranidium is not easy to compare in the two species owing to differences in the state of preservation, as already stated, but the preglabellar field of *P.*? *marri* is the longer (*sag.*), and its anterior border may be both better differentiated and more steeply inclined.

Of other British Ordovician proetids, "*Proetus*" *girvanensis* (Nicholson & Etheridge, 1878 : 169, pl. 12, figs. 7–10) from the Drummuck Group of Girvan has a shorter (*sag.*) preglabellar field and a larger glabella with three pairs of definite, though poorly-impressed, glabellar furrows. The eyes are also smaller and situated farther forwards. The trilobite described by Reed (1914 : 27, pl. 4, fig. 8) as *Cyphaspis jamesoni* and founded on a single imperfect specimen from the Balclatchie Group, has a cephalic form, including the development of the preglabellar field, not unlike *Proetidella*, but comparison of this species must await its further description.

The genus *Decoroproetus* Přibyl, 1946, with type-species *Proetus decorus* Barrande from the Silurian of Bohemia, was claimed by Přibyl (1953 : 60) as a synonym of *Proetidella*, but is now held to be generically distinct, separable by means of its well-defined basal glabellar lobes, and by the pygidium, the pleural furrows of which are better developed, more numerous, and turn backwards more strongly.

In *Ogmocnemis* from the Ashgill Series of Poland (Kielan, 1959 : 69–71) there are only traces, not always visible, of basal glabellar lobes, the anterior branches of the facial suture are less divergent frontally than in *Proetidella*, and the eyes are somewhat smaller, ending posteriorly a little farther in front of the pleuroccipital furrow. The reasons for separating the two generically may not be well founded, and *Ogmocnemis* may be a subgenus of *Proetidella*, if not actually synonymous with it. Whittard (1961 : 186) has laid stress on the importance of the preglabellar field in proetid classification, and has used Kielan's genus in describing *Ogmocnemis calvus* from the Lower Soudleyan of west Shropshire. It is difficult to distinguish the incomplete type cranidium figured by him from one of *Proetidella fearnsidesi*, and the species may range above the Harnagian Stage. Specimens in the Soudleyan of south Shropshire are almost identical with *O. calvus*, but their apparent differences from *P. fearnsidesi* may be merely the expression of a different lithology and preservation.

Family REMOPLEURIDIDAE Hawle & Corda, 1847

Genus ***REMOPLEURIDES*** Portlock, 1843

TYPE SPECIES. *Remopleurides colbii* Portlock, 1843 by subsequent designation of Miller (1889 : 565–566).

Trilobite remains broadly referable to this genus have been found at a number of different horizons and localities in the Cross Fell Inlier. In no instance has the hypostoma or pygidium been recovered, and the cranidia are usually damaged or distorted. Consequently it has not proved practical to assign specific names to the specimens or to make a firm comparison with other species, and in the following account they are arranged according to their geological horizons.

Remopleurides sp.

(Pl. 18, fig. 12)

1959*a*. *Remopleurides* sp., Dean, p. 214.

A small damaged cranidium, lacking the anterior glabellar tongue, is the only evidence of the genus in the Lower Melmerby Beds of the Alston Road section, where it was found at locality E. The specimen is too poor for detailed comparison, but the main portion of the glabella is generally similar to that of *Remopleurides biaculeatus*, described by Tripp (1954 : 664, pl. 2, figs. 1–12) from the Craighead Mudstones of the Girvan district.

Remopleurides sp.

(Pl. 18, figs. 6, 10)

1959*a*. *Remopleurides* sp., Dean, p. 214.

A single cranidium has been found in the Upper Melmerby Beds, Upper Longvillian Substage, at locality H by the Alston Road, near Melmerby. It is too badly damaged for comparison with other species, but it is interesting to note that the genus has been recorded by Harper (1956 : 389) from North Wales, in association with an Upper Longvillian fauna. The Alston Road specimen is of relatively large size, the basal breadth of the glabella being approximately 15 mm.

Remopleurides sp.

(Pl. 18, figs. 7, 8)

1959*a*. *Remopleurides* sp., Dean, p. 207.

Two small cranidia have been collected from Dufton Shales believed to belong to the middle portion of the Actonian Stage at locality B. 15 in Swindale Beck, and the better preserved is figured here. The species is probably new but its description must await additional material. Particularly conspicuous is the anterior glabellar tongue, which is quadrate, parallel sided, and steeply turned down frontally.

Remopleurides sp.

(Pl. 18, fig. 5)

1959*a*. *Remopleurides* aff. *burmeisteri* Bancroft : Dean, p. 207.

One flattened, incomplete cranidium from the Dufton Shales, Onnian Stage, *Onnia gracilis* Zone, at locality A. 12 in Pus Gill provides the only known record of the genus from the Onnian of the Cross Fell Inlier. Comparison with other species is difficult owing to the poor state of preservation, but the glabella lacks the glabellar furrows of *Remopleurides burmeisteri*, and the two are not now thought to be related. In south Shropshire *Remopleurides* appears rarely in the *Onnia gracilis* Zone and becomes more abundant in the succeeding *O. superba* Zone.

Remopleurides sp.

(Pl. 18, figs. 9, 11, 13)

1959*a*. *Remopleurides* sp. ind., Dean, p. 208.

Several fragments of *Remopleurides* have been collected from a thin band of sandy limestone within the highest beds of the Dufton Shales, Pusgillian Stage, at locality B. 25 in Swindale Beck. They comprise only flattened cranidia, with occasional thoracic segments and librigenae, but it seems unlikely that more than one species is represented.

The cranidia are too distorted for detailed comparison but bear a general resemblance to the cranidium of *Remopleurides colbii* Portlock (1843 : 254, pl. 1, figs. 1–6 ; pl. 24, fig. 10) from the Killey Bridge Beds of County Tyrone, Northern Ireland, a species redescribed by Whittington (1950 : 540, pl. 70, figs. 1, 2, 4, 5). Each of a group of three conjoined thoracic segments (Pl. 13, fig. 11) from Swindale Beck has an axial ring with a serrated posterior margin, a feature found not only in *R. colbii* but also in the Swedish species *R. validus*, described by Thorslund (1940 : 132, pl. 7, fig. 4) from the Lower Chasmops Limestone of the Lockne area. Three librigenae are known from the Pusgillian, one being figured here (Pl. 13, fig. 9). The librigenal spine is situated forwards from the genal angle, from which it is separated by what Warburg (1925 : 87) called a subgenal notch, a structure she described in *R. latus* var. *kullsbergensis* (1925 : 84, text-fig. 15). Subgenal notches are present in certain other species of *Remopleurides*, but do not occur in *R. colbii*.

IV. STRATIGRAPHICAL DISTRIBUTION AND RELATIONSHIPS OF THE TRILOBITES

Lithologically the Caradoc strata of the Cross Fell Inlier form what is essentially a succession of shales and mudstones, broken only by thin layers of impure, nodular limestone. Such a succession is in marked contrast with the, probably, shallower-water deposits of south Shropshire, and their thick development of arenaceous rocks. As might be expected, such differences in lithology are accompanied by variations in the composition of the shelly fauna, though it has generally proved possible to apply the faunal Stages of the type-succession to the Inlier.

In south Shropshire the local base of the Caradoc Series is usually formed by the Costonian Stage and falls within the *Nemagraptus gracilis* Zone, so that it may be equated with part of a profound and widespread marine transgression. Subsidence of the sea-floor probably continued through the whole of the time represented by the succeeding *Diplograptus multidens* Zone, believed to comprise the Harnagian and Soudleyan Stages, and may have been prolonged still further because the earliest-known Caradoc strata of the Cross Fell Inlier belong to the Lower Longvillian Substage and probably lie unconformably on the Borrowdale Volcanic Series, though an unfaulted junction of the two has not been found satisfactorily exposed.

The trilobites of the earlier Longvillian rocks in the Knock-Dufton and Roman Fell districts are neither abundant nor varied, comprising only a local species of *Proetidella*?, with occasional *Brongniartella* and *Broeggerolithus*, suggesting affinity with the northern part of the Inlier. The fauna of the Melmerby district is particularly characterized by an abundance of Trinucleidae, especially *Broeggerolithus nicholsoni* (Reed), accompanied by common *Kloucekia apiculata* (M'Coy), indicating an intimate connection with the faunas of the Drygill Shales of the northern Lake District and parts of North Wales, for example the Llanbedrog Mudstones. These two trilobites occur also in Shropshire, but in much reduced numbers. The genera *Chasmops*, *Conolichas*, *Illaenus* and *Toernquistia* at Melmerby suggest a connection with corresponding Scandinavian and Baltic faunas, whilst *Paracybeloides* occurs commonly in Scottish and North American Ordovician rocks, though it is known from stratigraphically early horizons in the Caradoc of North Wales.

In the Upper Longvillian of the Knock-Dufton district, *Brongniartella bisulcata* (M'Coy) is moderately common, as it is in south Shropshire, but its frequent Shropshire associate *Kloucekia apiculata* has not yet been found. Conversely, *Estoniops alifrons* (M'Coy) represents a group of phacopid trilobites which is widespread in the Baltic region and Scandinavia, as well as throughout much of North Wales, though unrecorded in Shropshire. Trinucleid trilobites have not been found in the Upper Longvillian rocks of the main part of the Inlier, and their absence has not been explained satisfactorily.

The trilobites of the Marshbrookian Stage are numerically abundant, though lacking in variety, and are generally comparable with those of Shropshire. *Brongniartella bisulcata* is moderately common and trinucleids, *Broeggerolithus* cf. *transiens* (Bancroft), fairly common. *Dindymene*, a European genus, is rare and has not yet been found in Shropshire, though it occurs also in the Upper Longvillian near Dufton, and in North Wales. A notable absentee from this horizon in the Cross Fell Inlier is *Chasmops*, a surprising fact in view of its abundance in Shropshire.

Owing to the lack of outcrops of Actonian strata in the Inlier the trilobites of this Stage are poorly known, but the assemblage of *Chasmops*, *Onnicalymene* and *Remopleurides* indicates connections with both Shropshire and Scandinavian faunas.

In the rocks of the Onnian Stage the resemblance between the fauna of the Dufton district and south Shropshire is most marked. *Onnia gracilis* (Bancroft), a species found also in North Wales, occurs in the Onny Valley and at Pus Gill, accompanied at both places by *Lonchodomas pennatus* (La Touche) and *Onnicalymene onniensis* (Shirley). In the succeeding zone the well-known Shropshire species *Onnia superba*

(Bancroft) is represented by a local subspecies *O. superba pusgillensis*. An interesting feature of the Onnian fauna at Cross Fell is the appearance of such genera as *Atractopyge*, *Calyptaulax*, *Pseudosphaerexochus* and *Tretaspis*, marking an influx from the Scandinavian area which assumed greater proportions during the succeeding Pusgillian Stage.

The Pusgillian has at various times been assigned to the Ashgill Series, but is now regarded as the topmost subdivision of the Caradoc Series. Trinucleid trilobites are abundant at this horizon, but the genus *Onnia*, so characteristic of the Onnian is absent and the family is represented only by *Tretaspis*. The latter genus is represented by several species or subspecies, all of which indicate close affinities with corresponding faunas in southern Norway and Sweden. Most of, if not all, the other trilobites in the Pusgillian are members of genera which have generally been thought to be more characteristic of Ashgill strata. The trilobite faunas of the Ashgill Series exhibit a uniformity and widespread distribution which are unknown in those of the Caradoc Series, and several genera and species are common to Scotland, the Anglo-Welsh area, Scandinavia and eastern Europe. The Onnian and Pusgillian strata of the Cross Fell Inlier are of particular interest because they demonstrate that the Ashgill elements invaded the Anglo-Welsh area at a relatively early date, after which there was a progressive increase in their numbers.

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